

The four intrahepatic structures and their interrelationship (Dorsal view) blue portal vein red hepatic artery yellow bile ducts gray hepatic veins

INTRODUCTION TO
HEPATIC SURGERY

by

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with an Introduction by

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Dedicated to the Memory of my Mother and to my Father

PREFACE

Comme la chirurgie des membres celles des viscères doit être régie par l anatomie de la région sur laquelle on opère et aussi par la connaissance des lésions contre lesquelles on intervient

La chirurgie viscerale doit tendre à être une chirurgie réglée comme l est depuis longtemps la chirurgie des membres Il est donc nécessaire de préciser au point d vue chirurgical tout ce qui touche à l anatomie des régions sur lesquelles on opère

HARTMANN 1901

A case of sickness in our own immediate surroundings confronted us with the fact that in certain cases of pathological affections many surgeons are deterred by the very great risks involved from resecting parts of the liver even though they feel this to be necessary

The operation techniques followed have certainly helped to cause an ambivalent attitude in the surgeon The methods introduced round about 1880 by Von Bergmann, Langebuch Von Eiselberg Keen and others are difficult and at the same time so primitive that serious complications threaten the patient both during and after the operation

For this reason, almost every successful partial liver resection was indeed still is, made public, from which it is obvious how hazardous the surgeons themselves considered this intervention and how relieved they were that their action was not followed by death (Bax and Schalm 1954)

Unaware at first of a recent analogous research by Couinaud we attempted to avoid the defects of the old method by taking new paths From the beginning we kept two criteria in mind in the first place the method to be developed must be anatomically justified which could by no means be said of the old method and in the second place it must be simple no method can be introduced into general surgical practice unless it can

be executed in most simple means which every operator has at hand' (Garre, 1907)

In order to meet the first criterion, we investigated the anatomy of the various intrahepatic structures The gaps in the knowledge of the course and interrelationship of the various intrahepatic structures, which we noticed in consulting the anatomy text-books, have long been recognized, though perhaps from another viewpoint than ours As an illustration of this may serve the observation by Mann, in 1942, that the history of the blood circulation in the liver lies buried beneath its own literature Thus, for example, in 1898 Cantlie in a short communication entitled "On a new arrangement of the right and left lobes of the liver , showed that "the present anatomical division (of the liver) into right and left lobes is unscientific and consequently untrue and untenable , whilst one still finds the liver described in current anatomy books as being built up of two lobes

In the last years, however, a gathering interest in the anatomical structure of the liver has become apparent A number of studies have appeared which deal with the structure of the lobules (Elias, 1953, Rappaport *et al*, 1954) as well as of the further anatomical structures distinguishable in the liver (Hjortsjo, 1948 Elias *et al*, 1952, Healey *et al*, 1953, Couinaud, 1952 and later) In the work of Couinaud the segmental construction is given great prominence We shall also devote a large part of our study to this problem, also in connection with the surgery of the liver

Of importance in surgery are some long forgotten publications by Wendel and Martens (1920), in which a description is given of an attempt to approach hepatic surgery in a manner that is anatomically justified They not only set the ligation at the liver hilum of the structures of that part of the liver to be resected as the crucial point of their method, but they also pointed out the importance of a certain anatomical plane in the liver along which the resection should be made

Another explanation of the tendency to solve the problems with the help of anatomy is found in the spectacular way in which lung surgery has profited from the study of the anatomy of the intrapulmonary structures Thanks to the application of plastics to the already old injection corrosion technique not only has the anatomical investigation of the various structures, and especially of their spatial relationship, become much simpler, but it has also produced completely new views, so much so indeed that we feel, as a result of our research, that a deepened knowledge of the anatomy of the liver not only helps to solve the problems of hepatic surgery, but also furnishes a possible basis for entirely new operative possibilities

Nijmegen May, 1955 HENRY GANS, M D

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From this place I wish in particular to record my debt to the Members of the Surgical Staff of the Jewish Hospital, Cincinnati Ohio who guided my first steps in surgery, and who granted me a leave of absence to finish this work To my former chief Dr A GROLLMAN, I would express especial thanks not only for his teaching and encouragement but also for his friendship

During the time that I was assistant in pathology in the St Canisius Hospital, Nymegen the director of the Department of Pathology, Dr J G PLETTE kindly made it possible for me to examine livers by the corrosion technique, and set time at my disposal for studying the literature For this and for the interest he showed I am very grateful

Dr H J LAMMERS, professor in anatomy at the Medical School of the R C University Nymegen gave me the opportunity to go over the material scientifically, without his greatly appreciated help and valuable criticism this work would never have developed into a dissertation

Dr H R BAX chief surgeon at the Municipal Hospital Arnhem, gave me the chance on several occasions to assist during operations on patients with symptoms of liver tumour or carcinoma of the gall bladder, and further I was able to operate on a few dogs in his clinic His interest and moral support' *were of considerable help to me and I am very* grateful to him

I should like to thank Dr J H J M PERNET surgeon at St Canisius Hospital for enabling me to put the acquired anatomical insight into practice on one of his patients

I received a great deal of help from Dr H J G WIERS, professor in pathology, Medical School, R C University, Nymegen, in working on the difficult subject of surgical hepatic pathology I am greatly indebted to him for his interest and his aid in solving the different problems

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H G

CONTENTS

INTRODUCTION

Hepatic surgery is not new There are literally hundreds of individual case reports and reports of small groups of operations upon the liver for various neoplasms and cysts, both benign and malignant Also in recent years attention has been focused upon the development of portal shunting procedures, envisaging the relief of ascites in the presence of cirrhosis Moreover aneurysms of hepatoportal vessels seem to be receiving more attention both as to clinical diagnosis and operative obliteration

Rational surgical procedures presuppose a detailed knowledge on the part of the surgeon of the anatomy of the organ and tissues in question The rather complex anatomy of the liver has been described in the past and the field again studied recently The facts as brought out by these older and more recent studies are certainly not appreciated by the majority of abdominal surgeons These points as well as many others are discussed at length by Dr Gans in this book Hemorrhage, which is the principal immediate complication in excisional hepatic surgery, will be rendered less likely when surgeons plan their operations, taking into consideration the anatomical principles so well described and emphasized here

In the general expansion of surgery interest in operations upon the liver is being revived judging from the recent literature Unlike the past when no one surgeon had appreciable personal experience in operations upon the liver, it may be predicted that such experience will increase

Dr Gans treatise is thus very timely He emphasizes the broad aspects of fundamental knowledge especially anatomy

that surgeons should appreciate in this type of work This volume should be read and digested by those anticipating operations upon the liver In addition, it should stimulate surgeons to think more about the liver as an organ that can be safely operated upon when the indications exist and not, as in the past, a field that would seem beyond surgical attack, or if attacked, a field highly fraught with danger

ALEXANDER BRUNSCHWIG, M D

New York City, N Y , August 15, 1955

Chapter I

ON THE SUBDIVISION OF THE LIVER

The subdivision of the liver both in its external aspect and on the basis of the internal arrangement of the intraorganic hollow structures has been the subject of profound study all down the ages

In this first chapter we shall follow the gradual unfolding of knowledge in the past on the external division and shall then proceed to discuss the internal division of the organ as described formerly and now Finally we shall see how this external subdivided pattern is related to the internal one

A THE EXTERNAL SUBDIVISION OF THE LIVER

The study of the anatomy of the liver is as old as culture itself It appears from Stieda s (1900) excellent paper on some ancient illustrations of human livers found by archaeologists that one of these objects a small clay model of a sheep s liver dates from the Babylonian era its age has been estimated at approximately 4–5000 years (fig 1)

The priests of those days were guided during religious ceremonies and when consulted by the observation of variations encountered in the entrails of animals whereby each variation observed had a specific meaning

Haruspicina was therefore not solely restricted to magic practices but included a science based upon a study of the

different forms and variations of the intestinal organs Stieda included these models in the curriculum for sacerdotal students

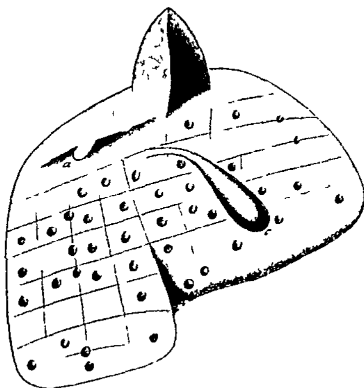


Fig 1 Baked clay model of a sheep's liver
(The liver tablet present in the British Museum) (Stieda 1900 by courtesy of Bergmann Verlag München)

Each lobe of the sheep's liver, the so called penulae or penacula also named fibrae or augmenta hepatis had its own significance, which appeared from the names mensa focus culter and auriga, by which each individual lobe could be distinguished from the others

Galen's conception, probably derived from his observations of animals, assumed that the human liver was also a lobated organ, an opinion which was corrected by Vesalius. "Quae enim dissectionem professores de jecoris forma ac penulis seu fibris (quas λοβοὺς Graeci vocant) commentantur e canum

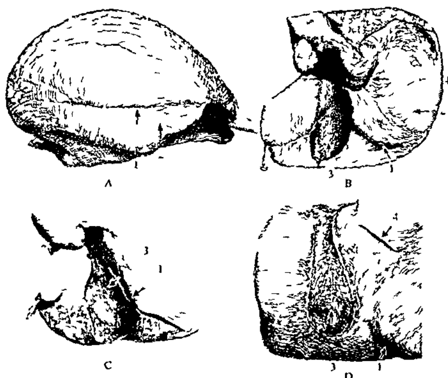


Fig 2 A liver from right lateral B C and D liver seen from behind 1 fissura interlobaris dextra 2 lobus dexter 3 fossa cystica 4 incisura dextra (after Ruge 1911)

potius et simiarum sectionibus, quas hominum didicerunt — Humanum enim jecur porcini et multo adhuc minus canini jecoris modo, non discinditur Nam unicum continuumque praecipue ipsius substantia corpus hominum jecor est

("The professors preferred to describe the external form of the hepatic penulae or fibrae (which the Greeks called lobi)

with the help of dissections on dogs and monkeys than to teach with the help of dissections on man

For the human liver has not as in the pig and still less as in the dog, a subdivision into lobes, the liver is a unity, and principally by its own substance one cohesive whole')

In most of the present day textbooks of anatomy one seldom encounters any other subdivision of the human liver than into right and left lobes The site of this division is marked by the incisura umbilicalis at its ventro caudal margin, the insertion of ligamentum falciforme at the ventral and cranial convexity and the fossa umbilicalis et ductus venosus (Arantii) at the dorso caudal c q visceral liver concavity

However, other divisional patterns have been described in the past, the first systematic description of the lobation which can be distinguished at the dorsal aspect of the human liver being by Von Haller (1764), who in his turn derived a great deal of his knowledge from earlier anatomical studies such as those of Vesalius, Eustachius and Spiegel

Von Haller's conception must be considered in some detail here, seeing that, on the whole, very little of this important work has been preserved as common knowledge

This author recognized two fossae sagittales at the dorsal liver surface united by a transverse one The latter is commonly indicated as 'sulcus transversus' or 'porta hepatis', which name is derived from the word πύλαι used by Aristotle (fig 25)

The fossa sagittalis sinistra corresponds with the fossa venae umbilicalis and fossa ductus venosi (Arantii), the fossa sagittalis dextra corresponds with the fossa vesicae felleae on its caudal and the fossa venae cavae on the dorso cranial side

In this way Von Haller distinguished four liver lobes, divided by three fossae namely the lobus dexter, located to the right of the fossa sagittalis dextra, the lobus sinister, located to the left of the fossa sagittalis sinistra, and the lobus medius located between the right and left fossae sagittales subdivided by the fossa transversa into an anterior part or lobus anterior

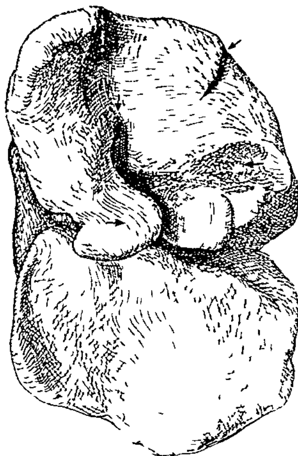


Fig 3 Liver dorsal aspect

1 incisura dextra 2 fissure in inferior margin (according to Ruge fissura interlobaris dextra) 3 fossa cystica 4 lobus caudatus (From Ruge 1911)

and a posterior projecting one, the lobus posterior, which Von Haller named later on lobus caudatus, bordered to the right by the inferior vena cava, to the left by the ligamentum venosum (Arantii), ventrally and caudally by the fossa transversa and dorsally by the cranio dorsal liver margin. The lobus caudatus was subdivided by Von Haller into two 'colliculi', the one located alongside the fossa sagittalis dextra, the colliculus caudatus, the other along the fossa ductus venosi, directed caudally, the colliculus papillaris, divided from each other by a shallow fissure. Later the term 'colliculus' was superseded by 'processus', but many names have been used other than these in the course of time.

We shall therefore first deal briefly with the *nomenclature* which has been used in the past to indicate different parts of the liver.

Sylvius (1478) designated the lobus caudatus as *lobus minimus*: 'Minimus ad portae exortum', Vesalius as *tuber*: 'qua duodenum exporrigitur et vena portae e jecore prodit jecur quodam tubere prominet' and Spiegel (1622) as *lobus exiguus*: 'lobus exiguus ab anatomicis nondum descriptus'. Von Haller introduced the name *lobus posterior*, later terming it the *lobus caudatus*, and its subdivision into the two aforementioned colliculi, Rex (1888) introduced the name *lobus omentalis*, Ruge (1909), *lobus venae cavae*, subdivided into a lobus dorsalis and a lobus descendens.

The lobus quadratus has also been denoted by various names, e.g. lobus anterior (Von Haller, 1764), lobus quadrangularis (Luschka, 1863), lobe principale moyen (Cuvier & Duvernoy, 1835), central suspensory lobe (Rolleston, 1861), lobus prae portalis (Ruge, 1909) and many other names.

For this reason, the adoption of an agreed uniform terminology was felt to be necessary. Accordingly, since the introduction of the B.N.A. terminology (1895), 'lobus caudatus (Spigeli)' is the accepted term for that part of the liver which

is located between the porta hepatis, ductus venosus and inferior vena cava and which is limited towards the right by an impression, corresponding with the insertion of the hepato duodenal ligament

'Lobus quadratus' (B N A terminology) stands for the part of the liver which is located between the fossa umbilicalis fossa cystica and sulcus transversus portarum, while by lobus dexter is understood the part to the right of and by lobus sinister the part to the left of the insertion of the falciform ligament

The differences in the external aspect of the various types of livers encountered in the different mammals had so puzzled many investigators that eventually *comparative anatomical* studies of the organ were undertaken The purpose of all these studies was to find one pattern of division to which all liver types both the lobated and the different unlobated varieties could be reduced

For the lobated liver as it occurs in pig dog and many other mammals shows a number of fissures radiating from the inferior or as the case may be ventro caudal liver margin towards the centre of the liver mass, dividing the organ into a number of lobes the number varying in the different mammalian species To realize such a pattern Ruge and De Burlet independently searched in a great number of human livers for rudimentary or fully developed fissures corresponding to those which are generally considered to be the main fissures of the lobated liver

Between 1909 and 1919 Ruge as well as De Burlet described a number of human livers showing fissures which answered their purpose (figs 2 and 81 p 96) These fissures one in the left liver lobe linke Seitenspalte (fissura sagittalis sinistra) and one in the right liver lobe rechte Seitenspalte (fissura sagittalis dextra) were the two new fissures which they added to the ones previously described by Von Haller namely the incisura umbilicalis and fossa cystica In this way both the lobat

ed and the unlobated liver can now be *subdivided into a lobus* lateralis sinister, a lobus centralis, composed of three 'Stamm*lappen'' (Ruge and De Burlet)*, namely the lobus centralis sinister the lobus praeportalis and the lobus dextro vesicalis, and the lobus lateralis dexter, located to the right of the 'rechte Seitenspalte'.

The lobus dorsalis, corresponding with the lobus caudatus was seen to be subdivided by a fissure into a *lobus venae cavae* turned to the right, and a lobus descendens towards the left *lateral lobe*.

In all investigations dealing with this subject (Duvernoy Rolleston, Flower, Canthie, Girard, etc.) the main body of the mammalian liver is divided either into two halves each of which is *subdivided into a number of lobes (Flower, Canthie,* and others), or into three main parts, *viz.* the right, middle (or central) and left lobe (Ruge and others), the middle lobe being subdivided into either two or three lobes (table 1).

We shall revert to this controversy later (Chapter VI).

B. THE INTERNAL SUBDIVISION OF THE LIVER

From Stieda's study it becomes obvious that the Haruspices not only observed the liver surface *but also the liver substance* by means of incisions, *the holes which can be seen in one of the* liver models, the 'cellae' of the Roman priests represent the open lumen of veins which, as we know, do not collapse but gape when this organ is incised[1].

One of the first and most comprehensive investigations of the anatomy of the human liver and its intrahepatic structures is *laid down in the study* 'Anatomia hepatis' by Glisson (1654). In this work the author deals extensively with the intrahepatic course *of both portal and hepatic veins* and their interrelationship. On account of the fact that Glisson was *able to clarify the relations of the different structures to each* other with the aid of some fine illustrations his work rose

TABLE I

Cuvier	1835	Left lobe	Left princip.	Principal lobe	Right princip.	Right lobe
Duvernoy				Middle princip.		—
				Suspensory lobe		Right lobe
Rolleston	1861	Left lobe	Left suspens. lobule	Central suspens. lobule	Right suspens. lobule	(superior lobe)
Owen	1868	Left lobe		Cystic (gall) lobe		Right lobe
Flowers	187[illegible]	Left segment			Right segment	
		Left lateral lobe	Left central lobe	Right central lobe		Right lateral lobe
Cantlie	1898		Left side		Right side	
Seregé	1901					
Girard	1830	Left lobe		Central lobe		Right lobe
Gurlt						
Leyh	1850	Left outer lobe	Left inner lobe	Right inner lobe		Right outer lobe
Leisering		Left lobe		Central lobe		Right lobe
and Muller	1873		Left	Central	Right	
			Central principal lobe (lobus medius)			Right principal lobe
Ellenberger and Baum	1891	Left principal lobe (lobus sinister)	Left central lobe	Quadrate lobe	Right central lobe	(lobus dexter)
				Stammlappen		
Ruge	1902	Left lateral lobe		Right segment		Right lateral lobe
and De Burlet	1911	(L[illegible] S[illegible] lappe)	Left segment ([illegible])	Preportal lobe ([illegible])	Lobus dextro-vesicalis	(Rechter Seitenlappen)
Rex	1888	Left inferior lobe	Left superior lobe	Central lobe		Right superior lobe
Meyer [illegible]	1911	Left lateral lobe	Left central lobe	Infraportal central segment	Right central lobe	Right lateral lobe
Charnock		Left lateral lobe	Left lobule		Right lobule	Right lateral lobe
Bradley	1909					([illegible])

After F. Meyer 1911

above the mere descriptive representation of data and therefore fully deserves to be counted as the starting point of the many following anatomical studies on the liver

There is no explanation for the remarkable fact that Glisson's name only has been preserved in connection with the

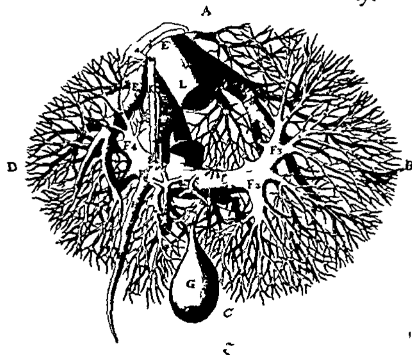


Fig 4a Relation of portal vein to hepatic vein seen dorsally (after Glisson 1654)

hepatic capsule whereas it is now a matter of common knowledge that this structure had been described previously by Walaeus or Valoeus (1640) the original description however, was ascribed to Jean Pecquet, a medical student who also gave a first account of the thoracic duct

The erroneous name "capsule of Glisson" was introduced by Francis Kiernan (1833) who dealing with the histological

liver unit the lobulus, described the portal canals as 'containing the hepatic ducts, the portal veins, the hepatic arteries, and the vaginal branches of all these vessels with the nerves and absorbents enveloped in a sheath of cellular tissue, first described by Glisson and called Glisson s capsule

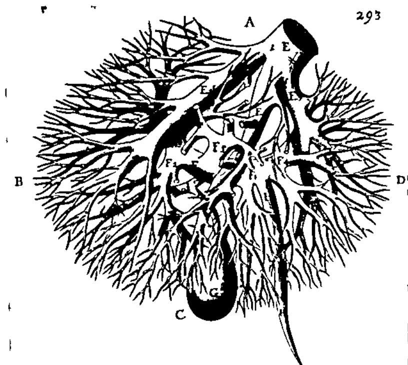


Fig 4b Ditto seen ventrally

From this quotation it appears that Kiernan especially pointed out that intrahepatically the bile duct arterial branch and portal vein branch run in close proximity to each other a common connective tissue sheath capsula Glissoni , envelops the corresponding structures The three structures entering or leaving the liver at the hilum or porta hepatis are therefore regarded as forming one morphological system



Fig C Specimen of portal vein Cranial aspect The plane of the median fissure forms an angle of 60–75 with the horizontal plane through the hilum the aperture of the angle being turned to the left
→ Anastomosis between bed of intrahepatic portal vein and phrenic veins



Fig 7 Specimen of portal vein

→ Sub-serosal vessels of the gall bladder Bed of gall bladder divided into two halves by the medial fissure

zontal plane through the hilum of about 60–75°, the opening of this angle is turned to the left (figs 5 and 6)

This fissure, *the fissura media, is a constant one*, showing very little variation from the course described above It divides the gall bladder into two parts of nearly equal size, one to the left and one to the right

When the portal vein is injected the subserosal venous capillaries of the gall bladder are filled even after previous ligation of the cystic vein Numerous anastomoses proved to be present between the minor intra hepatic portal branches and the subserosal vessels of the gall bladder (fig 7)

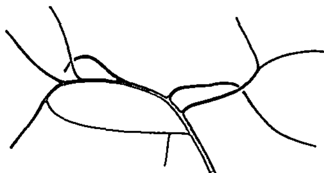
Both the quadrate and left lobes are situated to the left of this fissure thus they form the left part of the liver Moreover, the fissura media divides the caudate lobe into two parts located on either side of the fissure We possess several corro sion specimens of livers of which the right and left trunk of the hepatic arteries and/or bile ducts were alternately injected The injection was preceded by ligation of the left or right branch In none of our corrosion specimens could we find any anastomoses between the bile duct systems on both sides of the fissura media This confirms the recent observations of Schalm (1952), who used Von Hildebrand s X ray technique (see Appendix I) for his investigation

Three groups of arterial anastomoses between the vascular beds of right and left hepatic artery have been described by Martens (1920) and Segall (1923), both using that same tech nique, which were also present in our specimens

The first plexus is found extrahepatically in the hilar area (fig 8) It was present in about 25% of our specimens showing as fine branches arising from the right and left hepat ic artery

The second group of anastomosing vessels, which are branches of the fifth to the seventh order, were found in the area of the dorsal surface of the caudate lobe

These vessels cross the fissura media but they will cause hardly any bleeding during hepatic surgery because of their small calibre



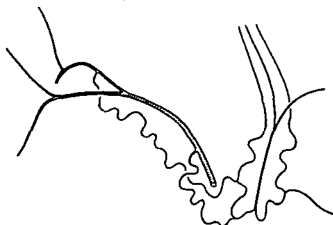


Fig 8 Arterial anastomoses in the h lar a ea

A third plexus which was present in only a few of our specimens consisted of intra and subcapsular single or multiple anastomosing usually very fine arterial branches which also may cross the fissura media In only one specimen did this plexus consist of vessels with a fair calibre

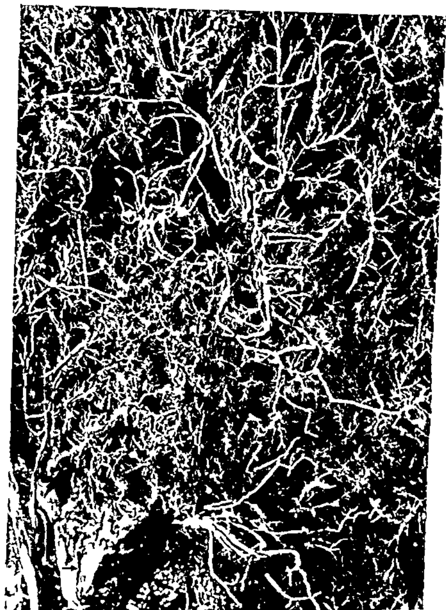


Fig 9 Subcapsular arterial anastomoses in the area of the caudate lobe
→ Portal vein

On the basis of these observations one may say that the liver is a *paired* organ for the arborization of its Glissonian structures The left liver half, though usually not as large as the right liver half is considerably larger than the left liver lobe



Fig 10 Microscopic section of the liver in the area of the fissura media A fissura media B portal triads

Histological examination of the liver was performed in the region of the fissura media The liver was cut perpendicular to the direction of this fissure On microscopic examination it was found in a series of sections that the slides—which were smooth and did not show any further tears or cracks—displayed a fissure at the same level where we expected the fissura media to be present This fissure as a tear formed a definite plane in the series of slices dividing the liver tissue in the centre of liver sinusoids Small portal triads were observed on either side of the tear (fig 10)



Fig 11 Ventral view of a portal vein specimen 1 Median fissure 2 Left interlobar fissure 3 Right interlobar fissure 4 Intersegmental fissure in right lobe

The gall bladder, as will be seen presently, develops out of the pars cystica located at the medial and caudal pole of the pars hepatica. During the development, this organ keeps its central position. It is therefore not surprising to see that the fissura media divides the fossa cystica into two parts of nearly equal size. Occasionally, however (8–10% of specimens) the fissura media may run along the left border of this fossa.

Two fissures can be distinguished in the liver halves described previously (fig. 11), dividing the Glissonian system of both halves into four areas, approximately corresponding to the liver lobes of the lobated liver, e.g. as in dog or pig (Rex, 1888, Hjortsjö, 1948, Healey *et al.*, 1953–54, Couinaud, 1954, Gans 1954).

There is one frontal fissure to the right and one sagittal fissure to the left of the fissura media. On the left side is the *left interlobar fissure* corresponding with the external division between the left and right lobe. It is marked at the inferior liver margin by the incisura umbilicalis, the medio visceral part harbours the sagittal part of the left portal vein trunk (recessus umbilicalis of Rex, 1888), which is identical with the most cranial portion of the left umbilical vein. The cranio visceral part of this fissure corresponds with the fossa of the ductus venosi (Arantii) which duct after originating at the curvature of the left portal vein trunk, runs cranially towards the inferior vena cava post natally it is obliterated. At the ventral surface it corresponds with a line slightly to the left of the insertion of the falciform ligament.

On the right side of the fissura media there is the *right interlobar fissure*; the ventral surface of the liver usually shows nothing to suggest its presence. Its intrahepatic course shows some variations depending upon the divisional pattern of the right portal vein trunk (figs. 12, 13 and 14). Generally, in the corrosion specimen this fissure cuts the lower margin of the ventral surface at a point between the fissura media and the right

Fig 12a

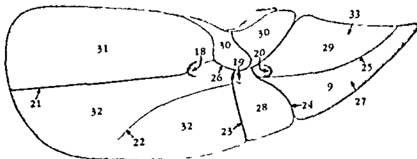


Fig 1 b

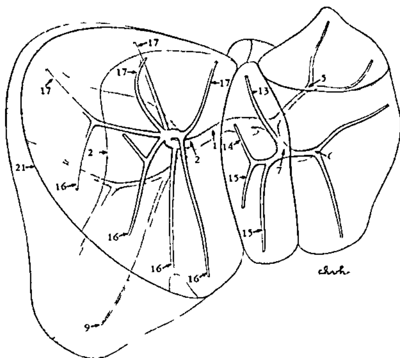


Fig 12c

Fig 12 Variations in the course of the portal vein I

A Dorsal aspect B Cranial aspect C Ventral aspect

1 Truncus dexter venae portae 2 vena paramedialis dextra 3 pars sagittalis venae portae sinistrae 4 saccus 5 vena cranialis lobi sinistri 6 vena caudalis lobi sinistri 7 vena paramedialis sinistra caudalis 8 vena dextra 9 vena paracystica 10 vena dextro caudalis 11 vena dextro cranialis 12 branch of the dorsal fan 13 vena paramedialis sinistra cranialis 14 branch of 7 to the ventro cranial area of the lobus paramedialis sinister 15 branch to the caudal area of the lobus paramedialis sinister 16 branches to the caudal area of the lobus paramedialis dexter 17 branches to the cranial area of the lobus paramedialis dexter 18 vena hepatica dextra 19 vena hepatica media 20 vena hepatica sinistra 21 fissura interlobaris dextra 22 fissura intermedia 23 fissura media 24 fissura interlobaris sinistra 25 fissura intersegmentalis sinistra 26 fissura dorsalis 27 segmentum ventro caudale lobi sinistri 28 lobus paramedialis sinister 29 lobus sinister 30 lobus caudatus 31 lobus dexter 32 lobus paramedialis dexter 33 segmentum cranio-dorsale lobi sinistri

Fig 13a

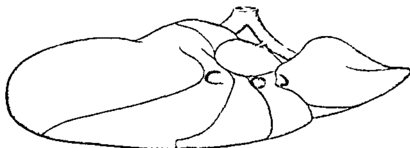


Fig 13b

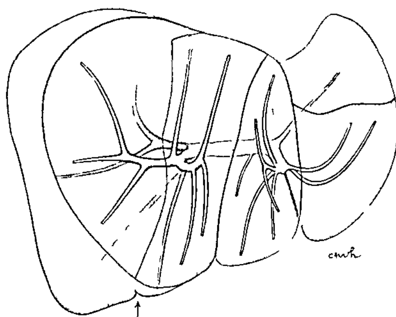


Fig 13c

Fig 13 Variations in the course of the portal vein II
A Dorsal aspect B Cranial aspect C Ventral aspect
→ An incisure which is present in the fresh liver does not correspond with the right interlobar fissure

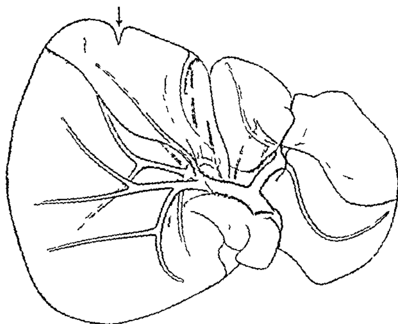


Fig 14a



Fig 14b

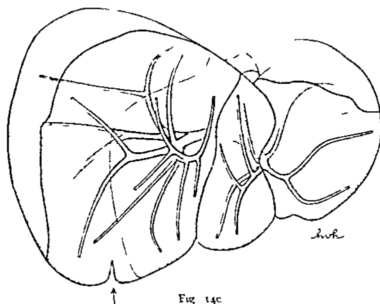


Fig 14c

Fig 14 Variations in the course of the portal vein III
A Dorsal aspect B Cranial aspect C. Ventral aspect
→ An incisure which is present in the fresh liver does not correspond with the right interlobar fissure

liver margin, situated at approximately one third of the dis tance from the latter Over the ventral surface it runs upwards for a distance of 10–15 cm parallel to the right liver margin (depending upon the size of the organ) following which it curves to the left to terminate at the right side of the inferior vena cava at the point where the right hepatic vein enters this

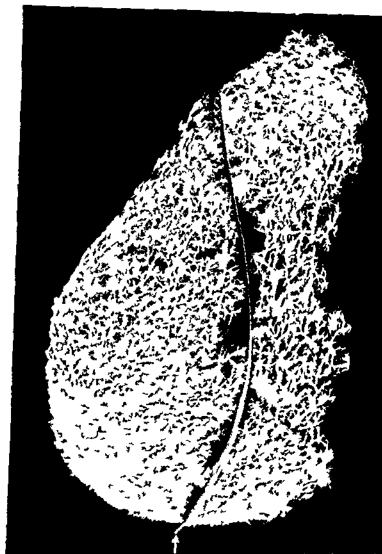


Fig 15 Specimen of portal vein Right lateral aspect → Right interlobar fissure

vessel This plane cuts the dorsal surface of the liver along a fairly straight line, going through the basis of the right paramedian vein This oblique fissure makes an angle of 30-45° with the horizontal plane with the opening of the angle turned to the right (fig 15)

In our polyvinylite specimens the three fissures described can easily be visualized by bending the casts slightly In this way the Glissonian areas can be distinguished without doing much harm to the normal anatomy

We were able to inject some of the lobar portal vein branches individually with different coloured plastoid A sharp demarcation of the lobar areas appeared to exist, without any anastomoses of the portal vein beds of two adjacent lobes

This fully agrees with the opinion voiced by Elias & Petty (1952), that portal shunts normally are absent It is probable that isolated anastomoses in a single specimen are the result of some local pathology not detected at autopsy especially since current observations in these laboratories have shown numerous portal anastomoses in cirrhosis'

Small arterial anastomoses are occasionally found between the different lobes, usually subcapsular seldom more centrally in location

C RELATIONSHIP BETWEEN THE EXTERNAL AND INTERNAL SUBDIVISION OF THE LIVER INTO LOBES

Is there any relationship between the external division of the organ (Ruge and De Burlet) and the internal one of the Glissonian system?

To answer this very important question for hepatic surgery we compared fresh livers with injection corrosion specimen

Concerning the left interlobar fissure and the medial fissure we have already answered this question for the fissura media is located in the fossa sagittalis dextra described by Von Hal

ler, which, as we have seen, is composed of the fossa cystica and fossa venae cavae, while the left interlobar fissure cor

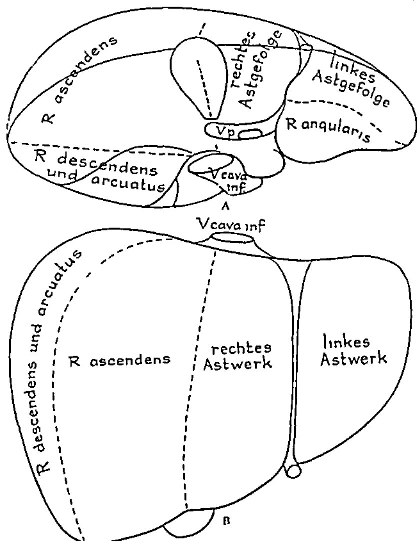


Fig 16 Division of the intrahepatic portal vein flow bed after Rex A Caudal aspect B Ventral aspect (re-drawn after Rex)

responds with the fossa sagittalis sinistra of Von Haller and not with the linke Seitenspalte described by Ruge, which is located far more laterally

To investigate the right interlobar fissure we injected a number of livers showing incisurae at the inferior margin of the right liver lobe, which according to Ruge, should correspond with the "rechte Seitenspalte" (fissura interlobaris dextra (fig 3 p 5) These two however certainly were not in

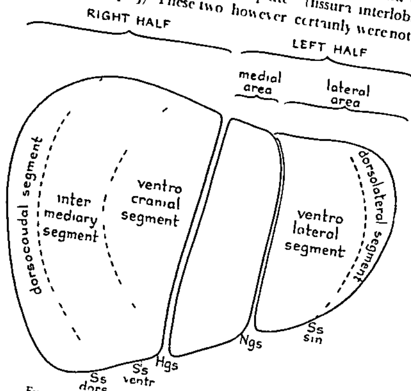


Fig 17 Division of the Glissonian system after Hjortsjo Ventral aspect (re-drawn after Hjortsjo)

variably related as is clear from figs 13 and 14 The plane of the right interlobar fissure an area which has been shaded in these figures usually cuts the dorsal liver surface either along the right margin or along a line through the right wall of the cavity which corresponds with the fossa cystica This deviates considerably from the line drawn by both Healey (1953) and Couinaud (1954) to mark off this fissure (fig 18–19)

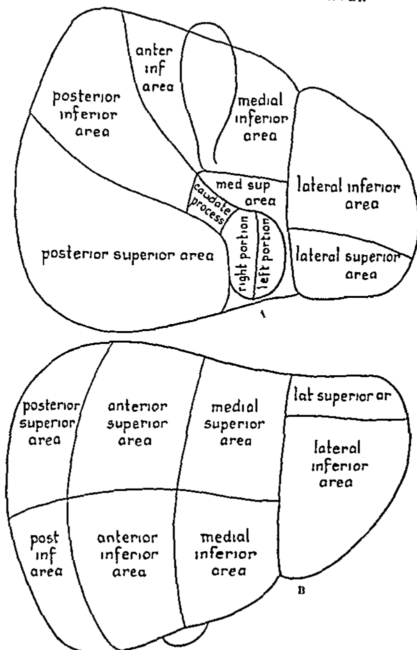


Fig 18 Division of intrahepatic bile-duct and hepatic arterial bed after Healey & Schroy
A Dorsal aspect B Ventral aspect (re-drawn after Healey & Schroy)

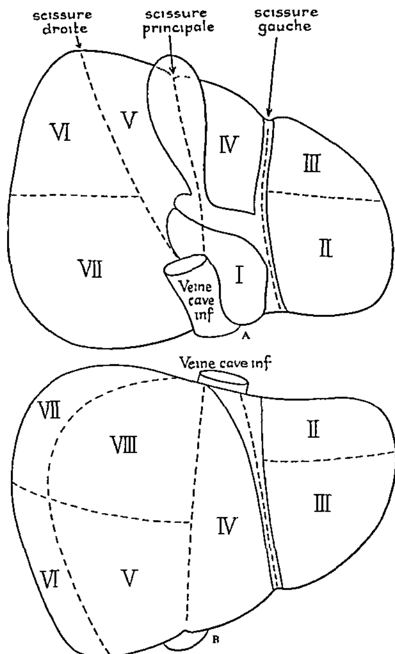


Fig 19 Division of the Glissonian system after Couinaud
A Dorsal aspect B Ventral aspect (redrawn after Couinaud)

The incisurae which were found in the fresh specimens are located at a good distance laterally from the point of intersection of this plane with the inferior liver margin.

In other instances, as in the livers reported by Ruge in 1911 (fig. 4), and in our specimen (fig. 20), a fissure was nevertheless found in the fossa cystica, which he described as follows: 'Subseröse Gefässe lagern in der Furche die sich dorsalwärts durch die Gallenblasegrube in oberflächlicher Lage verfolgen lassen, senken sich aber vor der Pforte in die Tiefe ein'.

("In the fissure lie sub serosal vessels which can be followed dorsally through the gall bladder cavity in a superficial position, but they sink into the deeper part of the tissue before reaching the portal fissure.")

In 10 % of our corrosion specimens Couinaud's line corresponded with the localization of the right interlobar fissure at the dorsal liver surface (fig. 14). In those instances we frequently found a shallow groove (sulcus) or a real fissure at this site in the fresh specimens, but the latter may also be present in those instances in which the fissure does *not* correspond with these grooves[1].

In view of the fact that Rex and Hjortsjo each invented different and rather intricate terms for the internal division of the organ, we aimed at adopting a *nomenclature* which would at the same time be consistent, anatomically, and easily understood and memorized. Therefore, we distinguished on the basis of the ramifications of the Glissonian system, a hepar dexter and a hepar sinister, divided from each other by the fissura media, for both lobes located on either side of this fissure we coined the term lobus paramedialis ventralis sinister, or dexter, as the case might be.

Both lobes lateral to the fissura interlobaris have been indicated as lobus dexter and lobus sinister, the lobus dexter to the right or laterally and dorsally to the fissura interlobaris dextra the lobus sinister to the left of the fissura interlobaris sinistra



1 2 3

Fig. 20. Liver, ventro-cranial aspect.
1 fissura interlobaris dextra, 2 gall bladder, 3 incisura umbilicalis

The lobus dexter, for the external division of the organ, does not correspond with the lobus dexter for the internal division, for which reason we shall henceforth designate the former as the *pars dextra (hepatis)*

The lobus caudatus, which is located between the right and left interlobar fissure, appears to be divided by the fissura media into two lobes lobus paramedialis dorsalis dexter and sinister The two interlobar fissures do not approach each other intrahepatically in the median line, but intersect the dorsal surface of the liver on both sides of the lobus caudatus *Hence the lobi paramediales dorsales are situated between* the right and left interlobar fissure These small lobes are separated from the lobi paramediales ventrales by a frontally placed fissure—called the *fissura dorsalis*—which cuts the cranial pole of the liver in an arc (fig 12) Caudally, this fissure cuts the superior wall of the fossa transversa (or porta hepatis) in virtually a straight line

It is currently known that the lungs can be seen to be divided into a number of lobes On injection of the bronchi and pulmonary arteries followed by corrosion of the organ, it appeared that the external division into lobes corresponded with the internal arborization of the bronchi as well as the arteries but *subdivision of the lobes into segments, not present on the outer* part of the lung were also found in this way

Does this likewise apply to the liver?

We find that the different lobes described previously for the Glissonian system, like those of the lungs similarly fall into a number of *segments** *The term "segments* was probably introduced by Flowers (1872), though he used it in the reverse sense Quand le foie est ainsi partage en deux masses principales, ne presentant pas de subdivisions, on peut les nommer

* The right word is actually sector because the liver area indicated by this term is three-dimensional Our use of the less correct term segment is in deference to its general adoption in medical nomenclature *e g* in pulmonary anatomy and surgery

lobe droit et lobe gauche, mais, lorsque ces deux masses sont divisees on doit les designer sous le nom de segments droit ou gauche du foie, en reservant le nom de lobe pour leurs sub divisions"

(Thus, when the liver is divided into two main parts showing no subdivisions one can call them the right lobe and the left lobe, but when these two parts are sub divided one must refer to them as the right and left segments of the liver reserving the name lobe for their sub divisions)

Rex (1888) did not speak of segments for the subdivisions which he found in his *portal vein* specimens He however distinguished two areas in the lobus dexter Astgefolge des Ramus Ascendens and Astgefolge des Ramus Descendens und Arcuatus and two delimited areas in the left liver lobe Linkes Astgefolge and Astgefolge des Ramus Angularis (fig 16)

Hjortsjo (1948) is alone (see fig 17) in stressing the fact that his S[5] sin represents a sagittal fissure He did not note any of the transversal fissures described by Healey *et al* and Couinaud (figs 18 and 19)

Couinaud (1954) who distinguished eight segments in dicated by numbers instead of names arrived at the division which does not correspond with his conception of the sym metrical arrangement of the intrahepatic Glissonian structures (see page 110) moreover his division differs considerably from Healey s *et al*, (see figs 18 and 19) who came to a division into ten segments

It will be clear from this brief survey that there are some discrepancies between the results of the various recent findings and these call for further investigation Our own work how ever has facilitated the task of discovering exactly how these lobes were subdivided there are in fact several alternative means of establishing the segmental borders with absolute certainty namely

(1) by bending the casts apart In this way the different segments stand out clearly,
(2) by breaking off the segmental structures of the Glissonian system at their base,
(3) by *injecting the segmental structure of each individual* segment with plastics of different colours

Our specimens show that the left liver lobe is neither subdivided by a transversal nor a sagittal (Couinaud, Healey), but by a frontal plane, which takes a different course from that indicated by Hjortsjo (*compare fig 17 with fig 12*) *This* fissura intersegmentalis lobi sinistri divides the left liver lobe into a segmentum cranio dorsale and a segmentum ventro *caudale*

As far as can be judged from Ruge's illustrations, the fissura intersegmentalis lobi sinistri seems to correspond with the one described by *this author on the dorsal surface of one of his fresh* livers, which he indicated as 'linke Seitenspalte , described as a Querspalte ' (a transversal fissure!) Although we never encountered this fissure in our fresh specimens, a *slight hint of* it may occasionally be found on the dorsal left lobar surface as a shallow groove

Unlike the left lobe, the lobus dexter is divided *by a transversal fissure (see fig 11) into a segmentum craniale and a* segmentum caudale

No clear cut transverse fissures are present in either paramedian *lobe, this contrary to Healey* and Couinaud

A sagittal fissure, *fissura intermedia*, can be recognized, dividing the right paramedian lobe into a medial and lateral territory, *to which we shall revert in* Chapter III (page 59)

Conclusions The liver can be divided both on its external aspect and on the basis of the arborization of structures of the Glissonian system

In the *external subdivision* we distinguish a pars dextra and a pars sinistra, lobus quadratus and lobus caudatus

For the internal division we were able to confirm the fact that the liver is a paired organ. Moreover, the intrahepatic Glissonian flow bed is divided into four ventral lobes viz. the lobus dexter and sinister and both lobi paramediales ventrales and two dorsal lobes, the lobi paramediales dorsales, which only partly correspond with the external division.

The grooves seen on the visceral surface do not always correspond with the fissures recognized for the internal subdivision.

Both the lobus dexter and lobus sinister are subdivided into two segments.

Chapter II

EMBRYOLOGY OF THE LIVER

Having considered the division of the liver on the basis of the arborization of the Glissonian system in the preceding chapter, we shall now briefly survey the most prominent features in the development of the human liver which are pertinent to the present and future interpretation of findings

As is generally known, the *liver parenchyma* develops from the entoderm of the ventral wall of the fore gut The first "Anlage of the liver parenchyma is paired in the turtle, some birds and reptiles (Ihle *et al*) and also was thought initially to be paired in the human embryo (Hertwig, 1888), until Thompson (1908) found only one hepatic bud in a 2½ mm foetus

This bud arises in a 2–2½ mm (*12–17* somite stage) embryo, which is at an earlier stage than that at which the lungs and pancreas develop

The hepatic cells invade the septum transversum, located between the pericardial cavity on the cranial and the yolk stalk on the caudal side the invasion is accompanied by destruction of part of the mesodermal cells, which are the original constituents of the septum Initially the cells lie embedded in between the septal mesoderm, but they quite soon increase in density on account of their rapid proliferation

The liver cells are arranged in a trabecular spongework around sinusoids, lined with a layer of flattened mesothelial cells, through which the blood from the vitelline as well as the

umbilical veins is distributed The rich blood supply of the organ accounts for its rapid enlargement, taking place at first in a lateral and dorsal direction, as right and left hepatic masses soon followed by that in a ventral and caudal direction In the first stage of its development the enlargement of the liver is out of proportion to that of the rest of the foetal organism

At a very early stage the hepatic bud divides into a cranial part which develops into the liver parenchyma (pars hepatica) and into a dorso caudal part, developing into the gall-bladder and cystic duct (pars cystica)

The pars cystica initially located intrahepatically (De Burlet, 1911) grows out as gall bladder and cystic duct During the development of the liver the gall bladder probably occupies a central position Die ursprungliche Lage der Gallenblase entspricht der Medianebene, dass diese ursprungliche Lage aber im Laufe der Entwicklung dieselbe bleibt ist nicht bewiesen, eine Verschiebung an der Leberintestinalflache ist wegen der fruhen, tiefen Einbettung im Parenchym nicht wahrscheinlich (The original position of the gall bladder corresponds to the median plane, but there is no proof that this original position remains the same in the course of development Owing to the early deep embedding in the parenchyma it is unlikely that there is any displacement with regard to the facies intestinalis hepatis) (De Burlet)

The hollow stalk, connecting the pars hepatica with the duodenum differentiates into common bile and common hepatic duct as also into both hepatic ducts and their intra hepatic ramifications

The development of the *hepatic venous system* in connection with the subdivision found in the portal flow bed presented a problem It appears that during the process of lateral extension of the liver the dorso lateral surfaces of both hepatic masses soon meet the vitelline veins running along the primitive alimentary tract which are broken up into sinusoids, invaded by the liver cells

Extrahepatically each vein differentiates into a distinct distal* or afferent and a proximal* or efferent structure for the liver We imagine, with Mall (1906), that at this moment two primary lobules come into existence, towards the end of the third week, *each one with its own afferent and efferent vein* If this is what happens, then it is obvious that, though the parenchymatous "Anlage" of the liver *is unpaired, its internal* arrangement is from the very beginning a paired one, around both vitelline veins

The umbilical veins, which run in the lateral abdominal wall, communicate in the septum transversum with both efferent vitelline veins and discharge their blood by way of the truncus vitello umbilicalis into the sinus venosus

Both lobules, extending *into* the septum, subsequently reach the umbilical veins, which in their turn are broken up into sinusoids *The ingrowing cells derived from both primitive* lobules, should we imagine, form two new ones, again each with its own afferent and efferent vein At this stage of four primary lobules corresponding with the primitive lobes, the sinusoids still consist of one wide system of channels which are in open communication with each other The primary lobules are very small at the end of the second month the diameter is 0 5 mm, at birth *1* mm and in the *adult 1²* mm (Mall, *1906*)

In general, the same course of events takes place during the *development of all mammalian livers* As far back as 1900 Choronshitzky stated that the right half of the liver of a sheep embryo is supplied by the right vitelline as well as the right umbilical vein while the left side is supplied by both corres ponding left veins Charnock Bradley (1909) found in pigs the left and right umbilical veins to be *located* on either side of the gall bladder

Several changes occur *in the extrahepatic venous system*, subsequently followed by intrahepatic rearrangements, during which the two intrahepatic flow beds, those of the porto-

* In relation to the heart

umbilical afferent and efferent hepatic vein system, are formed

The afferent or distal segments of the originally *paired* vitelline veins communicate by three cross anastomoses, the cranial and caudal ones being located ventrally and the medial one dorsally to the alimentary tract Following obliteration of the right vitelline vein part, which is located in between the caudal and medial anastomoses and that part of the left vitelline vein in between the cranial and medial anastomoses, onlv the right vitelline vein is left over to transport the blood from the alimentary tract to the liver This vein assumes a composite S shape which as superior mesenteric vein after rotation of the gut curves over the pars inferior duodeni and, as portal vein underneath the head of the pancreas and the pars superior duodeni (His, 1885)

Moreover, the extrahepatic distal part of the right umbilical vein is obliterated in the 6 mm embryo, the proximal part located in the septum transversum has been incorporated in the extending liver tissue as vena hepatica dextra located between the right and left paramedian lobulus

Von Haller (1774) while discussing the changes which occur at birth remarked that blood returning from the placenta passes into the liver through vessels that in the foetus are offshoots of the umbilical vein but in the adult are off shoots of the portal vein (Barclay *et al*, 1952) Probably the same thing happens during the early development of the organ when the right distal umbilical vein is obliterated

The four primitive lobules which are formed in this way are thought by us to correspond with the four ventral Glis sonian lobes described previously After the obliteration of the proximal left vitelline vein the blood of both paramedian lobes is discharged by way of the right proximal vitelline vein which shifts to a position in between both lobules its extrahepatic part the ductus hepato cardiacus becomes the proximal part of the inferior vena cava

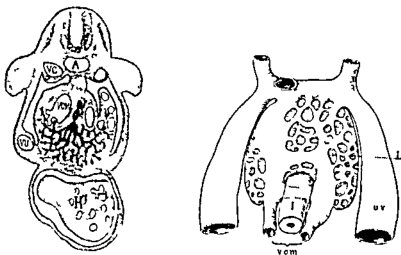


Fig 21a

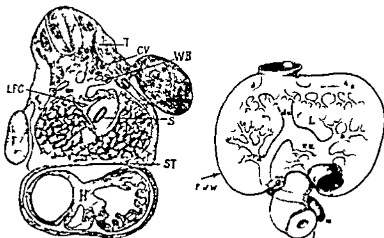


Fig 21b

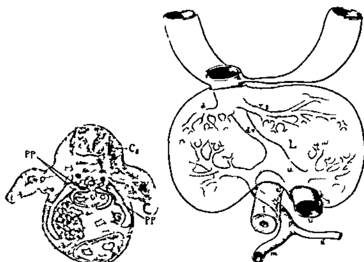


Fig 21c

Fig 21 Semi-diagrammatic reconstruction of the venous systems of the liver A embryo of 4½ mm B embryo of 7 mm C embryo of 9 mm
1 liver u v umbilical vein v o m omphalo-mesenteric vein i intestine c cardiac vein s stomach l p c lesser peritoneal cavity h heart s t septum transversum r u recessus umbilicalis p p pleuro-peritoneal cavity p vena portae d v ductus venosus r h d ramus hepaticus dexter r h s ramus hepaticus sinister r a ramus angularis r a [1] ramus arcuatus (from original of figs 9 10 16 17 19 and 20 Franklin P Mall Am J Anat V 256 260 and 261)

This process of internal rearrangement starting at the end of the fifth week has been described by Mall (1906) in the following way The hepatic and portal veins are telescoping they are beginning to dovetail with each other The different stages of this process are represented in fig 21
The four ventral lobes can be recognized as separated for a shorter or longer period in the embryo De Burlet still found clearly marked fissures radiating from the margo inferior towards the centre of the liver mass in a 32 mm embryo These fissures coincided with the medial and interlobar ones described for the adult human liver (fig 22)

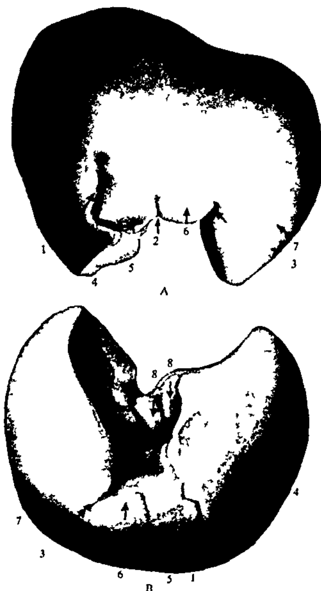


Fig 22 Model of a liver belonging to a human embryo of 32 mm (De Burlet 1911)
A Ventro-cranially B posterior aspect
1 Fissura interlobaris dextra 2 fissura media 3 fissura interlobaris sinistra 4 lobus dexter 5 lobus paramedialis dexter 6 lobus paramedialis sinister 7 lobus sinister 8 lobus caudatus

The lobuli paramediales dorsales (caudati) develop somewhat later than the four ventral lobules Mall described their formation thus With the subdivision of the middle and left hepatic veins into two branches each, six primary lobules are seen to correspond with the six primary lobes of the mammalian liver and 'The primary lobules radiate from a centre and have between them the main trunks of the portal veins, each interlobar vein at this stage is to form a main trunk in the adult

The development of the *hepatic artery* takes place after fusion of the most cranial ventral branches of the descending aorta into the coeliac artery One of its branches takes its course to the liver as hepatic artery

Many errors in the development of this artery account for the numerous variations encountered in the hepatic arterial blood supply (Rio Branco, 1912)

Initially the liver extends in a lateral direction then in a ventral and caudal direction the site at which both vitelline veins enter the liver the *hilum*, originally located near the lower liver margin being pushed up into a relatively more cranial direction Thus the portal vein enters the organ at its dorsal surface slightly cranially and dorsally to the bile ducts which have been differentiated from the original connective stalk between hepatic bud and gut

At the hilum of the adult human liver we still find traces of the original situation in the form of a figure H the two vertical bars of which represent the right and left vitelline veins while the horizontal bar corresponding with the sulcus transversus of Von Haller, represents the aforementioned cranial anastomosis between the two vitelline veins The right bar is identical with the main portal vein and right portal vein trunk The left vitelline vein corresponds with the medial portion the left umbilical vein with the lateral portion of the pars sagittalis venae portae sinistrae the left cranial bar with the ductus venosus (Arantii) (fig 23)

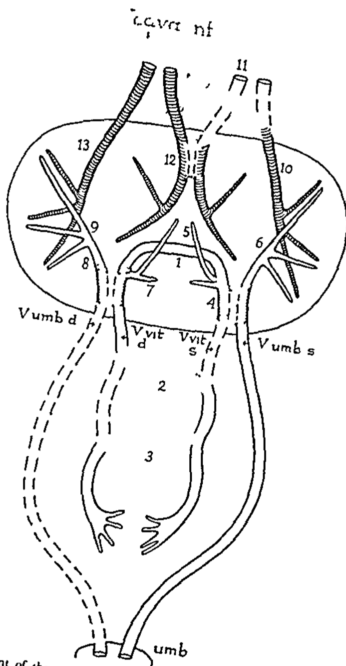


Fig 23 Development of the intrahepatic venous systems in diagram Anastomoses between the venae omphalo-mesentericae 1 cranial anastomosis 2 medial anastomosis 3 caudal anastomosis 4 pars sagittalis 5 venae paramediales sinistrae 6 vena cranialis and caudalis lobi sinistri 7 vena paramedialis dextra 8 vena dextra 9 vena cranialis and caudalis lobi dextri 10 vena hepatica sinistra 11 obliterated proximal part of the left vitelline vein 12 vena hepatica media 13 vena hepatica dextra

Chapter III

THE GLISSONIAN SYSTEM

Prior to a systematic discussion of the structures comprising the Glissonian system extrahepatically in the hepato duodenal ligament and the hilum as well as intrahepatically, and of the relationship of the lobar and segmental structures to the hilum, the lobes and segments concerned we first have to define the conceptions Glisson s capsule and hilum '

Glisson s capsule The triangular, coronary and falciform liga ments the lesser omentum the hepatic capsule the hilar and the intrahepatic connective tissue, all blend without any tran sition because these structures are derived from the mesoderm of the septum transversum The hepatic capsule named after Glisson, dives into the organ at the hilum as a sheath around the portal vein branch and its corresponding artery and bile duct for which reason all the hilar connective tissue has—in our opinion rather arbitrarily—likewise been considered as Glisson s capsule In the dissecting room specimen represented by fig 24 the two intrahepatic systems are readily dis tinguished but the three structures of which the Glissonian system is composed are so densely interwoven that it is ex ceedingly difficult to separate them

Hilum The hilum is defined as the area at the dorsum of the liver where after removal of all loose connective tissue Glis

sonian system structures can be recognized extrahepatically prior to their penetration into the body of the liver It includes the sulcus transversus (Von Haller), the umbilical fossa and the incisura dextra, the latter extending from the right margin of the porta hepatis in a caudo lateral direction This incisura



Fig 24 Dissecting room specimen dorsal aspect Glissonian system A at the hilum B intrahepatic C the medial hepatic vein

is present in approximately 80 % of livers, its length varies from 2 to 5 cm After drawing back the overhanging liver margins which partly cover the incisura, a rather shallow space appears which is a continuation of the porta hepatis The hilar structures can be further dissected out at the bottom of this space

The relationship between the different hilar structures

becomes clear during the surgical approach to this region (fig 25), with the ventral liver surface turned cranially and its inferior margin now directed upwards In this way one faces the dorsal or visceral surface of the liver

In this approach the most caudally situated structures—bile ducts and arteries—first become visible, while the most cranially located one—the portal vein—lies deep down be coming visible only after previous dissection of both the bile ducts and the arteries

After this brief description of the hilum, we must now dwell on the topography of the Glissonian structures in the hepato duodenal ligament and at the hilum of the liver as observed during hilar dissection

While removing the connective tissue along the free margin of the hepato duodenal ligament the first structure to become visible is the common bile duct with the appropriate hepatic artery on the medial side These two structures overlie the portal vein The hepatic artery is the first of these structures to ramify in the ligament the course of the right branch of the artery usually being underneath the common bile or common hepatic duct, as the case may be, and gives off the cystic ar tery towards the gall bladder Mostly two, occasionally three, or even four branches of the right hepatic artery can be dissect ed at the hilum, more often than not, all of them are situated over the corresponding bile ducts which, in their turn, run on top of the right portal vein trunk

The vena portae communis divides upon entering the hilum near the right hilar margin into the two main divisions the truncus dexter and truncus sinister venae portae

Extrahepatically the division of the truncus dexter into two large rami can be visualized following retraction of the over hanging right hilar margin or the margins of the incisura dextra as represented in fig 25

The first ramus usually runs as far as it can be visualized

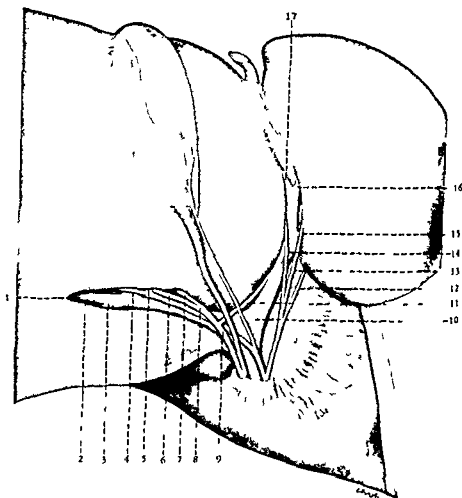


Fig 25 Hilum after removal of the Glissonian capsule (Surgical approach) 1 vena dextro-caudalis 2 incisura dextra 3 vena dextro-cranialis 4 arteria dextra curving around the basis of the vena paramedialis dextra 5 arteria paramedialis dextra 6 ductus dexter 7 ductus paramedialis dexter 8 ductus hepaticus dexter 9 ductus hepaticus communis 10 truncus sinister venae portae 11 ductus hepaticus sinister 12 arteria cranialis lobi sinistri 13 arteria caudalis lobi sinistri 14 arteria paramedialis sinistra 15 vena cranialis lobi sinistri 16 vena caudalis lobi sinistri 17 vena paramedialis sinistra caudalis

in a ventro caudal direction, the second ramus runs in a lateral direction.

At the bottom of the sulcus transversus the length of which varies from 2 to 5 cm, there comes the truncus sinister venae portae "pars transversa trunci sinistri venae portae" (Elias & Petty, 1952), which can be dissected.

Caudally to the pars transversa we find the left hepatic duct which lies within some millimetres of the hepatic tissue towards the site of its junction with the right hepatic duct; however this distance ranges between 0.5 and 5 cm. Here, too, retraction of overhanging liver portions facilitates the exposure of the junction. The connective tissue at the hilum, which is generally quite loose in consistency, may nevertheless show local condensation between the inferior margin of the caudate lobe and the junction of the hepatic ducts; in that event it may hamper their proper dissection.

The left hepatic artery is much more superficially located than the left hepatic duct or the truncus sinister venae portae. It can be followed without any difficulty up to the point where the different segmental branches penetrate into the liver parenchyma.

The arterial branches become visible first of all but further dissection also reveals the portal vein branches running to the caudate lobe. Next, a separate arterial branch was often seen running to the quadrate lobe and usually two other branches which disappeared into the left liver lobe.

The pars transversa trunci sinistri venae portae curves at an angle of 95–125 in a caudal direction, forming the sagittal part located in the umbilical fossa (recessus umbilicalis of Rex). This part is easily accessible from the dorsal liver surface after removal of the overlying connective tissue.

A large portal vein branch arises at the curvature and can be followed together with its corresponding artery, occasionally also with the corresponding bile duct which, if it runs ventrally to this vein, remains invisible for a distance

of 0.5–1.5 cm after leaving the body of the left liver lobe

The sagittal part of the left portal vein trunk ends abruptly in a bag like structure, indicated as *saccus*

Two groups of vessels can be seen to arise from the saccus namely a group originating at the medial aspect, running to the quadrate lobe, and a group arising at the lateral aspect, disappearing into the caudal part of the left liver lobe All these structures are accompanied by their corresponding arterial branches and bile ducts

Occasionally a bar of liver tissue overlies the saccus and has to be divided to give access to this region

It is thus that the different Glissonian pedicles can be visualized at the hilum

Before we compare the relationship between the various Glissonian pedicles which have been visualized at the hilum and the lobes and segments of the intrahepatic Glissonian system, we must consider the common denominator of the different variations in the intrahepatic course of the three structures of the Glissonian system as encountered in our corrosion specimens In doing so, we shall confine our description to the branches of the first and second order, both from the portal vein hepatic artery and from the bile ducts

As we have seen, the territory of the left portal vein trunk is sharply marked off from that on the right and does not coincide with the left liver lobe The left portal vein trunk of which the main ramifications show very few variations in the different casts, consists of two parts, a pars transversa and a pars sagittalis, corresponding with those previously visualized at the hilum, the latter is the remnant of the fused left vitelline and left umbilical vein (fig 26) From the transverse part length 2–5 cm, two to three small branches can be seen running cranially towards the caudate lobe, more in particular to the dorsal part of the lobus paramedialis dorsalis sinister *venae caudatae sinistrae* (fig 27)

Occasionally a ramus can be distinguished at the inferior aspect of the transverse part running into the caudal part of the left paramedian lobe *vena paramedialis sinistra caudalis superior*



Fig 26 Portal vein specimen ventral aspect
1 truncus sinister 2 pars sagittalis 3 vena paramedialis sinistra caudalis 4 vena paramedialis sinistra cranialis 5 vene caudalis lobi sinistri 6 vene cranialis lobi sinistri 7 truncus dexter 8 vena paramedialis dextra 9 vena dextra

The transverse part curves at an angle of 95–125 in a caudo lateral direction forming the sagittal part, located in the dorsal part of the left interlobar fissure In the foetus the ductus venosus (Arantii) arises from this curvature, directed towards the inferior vena cava



Fig 27 Truncus sinister venae portae with its ramifications ventral aspect
1 truncus sinister 2 pars sagittalis 3 4 and 5 venae paramediales sinistrae
6 venae caudati 7 vena caudalis lobi sinistri 8 vena cranialis lobi sinistri
9 vena parumbilicalis

At the site of the caudal bend, a large branch arises at the convex surface of the curvature, running in a latero cranial direction the *vena cranialis lobi sinistri* Its course is fairly straight When traversing the cranial part of the left liver lobe, this branch is close to the dorsal surface of the liver and can be reached easily from the dorsal aspect The ramifications of this vessel correspond with the *segmentum cranio dorsale lobi sinistri*

The sagittal part ends abruptly in a bag like structure, which was described previously as the saccus Several vessels arise here the first, as a group, originating at the medial aspect of the saccus the *venae paramediales sinistrae caudales* The ramifications of this group of vessels supply the quadrate lobe almost entirely and coincide with the caudal part of the lobus para medialis sinister The second vessel, as a large single branch, though occasionally as several branches arises at or along the lateral aspect the vena intermedialis and *vena caudalis lobi sinistri* The ramifications of these vessels correspond with the *segmentum ventro caudale lobi sinistri*

One branch usually arises from the ventral aspect of the pars sagittalis sometimes, however, from the medial aspect at a variable point located between the margo inferior of the saccus and the curvature, *vena paramedialis sinistra cranialis*, supplying the cranial and ventral part of the lobus paramedialis sinister

The *truncus dexter venae portae* shows more variations than the left portal vein trunk Here we only will describe the course of this vessel as it was usually encountered in our specimens in a subsequent chapter we shall describe the most prominent variations seen in our casts

This vessel runs transversely for a variable distance ranging from 0–3 cm before it bifurcates into two rami prior to their disappearance into the body of the right half of the liver (fig 28)

The first branch *the vena paramedialis dextra*, is of considerable



Fig 8 Truncus dexter venae portae with its ramifications ventral aspect 1 vena paramedialis dextra 2 vena dextra 3 ventral fan branches 4 dorsal fan branches 5 vena cranialis lobi dextri 6 vena caudalis lobi dextri 7 vena paracystica

calibre and usually runs in the same direction as the vena
portae communis Glisson referred to it as (ramus) quintus
anterior (a fifth anterior branch), Rex as ramus ascendens
which as ramus cysticus takes a variable origin in the different
mammalian livers, a feature also found in the human liver by
Deve (1907) to which we shall revert in the next chapter

This vein, occasionally these veins the arborization of which
corresponds with the territory of the lobus paramedialis dexter
usually runs in a ventro caudal direction in fresh livers

The ramuli arising from this vessel vary in size number and
direction, a fact which may have an influence upon the size and
shape of this lobe as such (figs 12 13 and 14)

The general picture presented by these variations is two
fan shaped groups of ramifications one at a variable distance
(0–3 cm) from its origin, for which we coined the name *dorsal
fan* and the second from the distal part of this vein called by
us the *ventral fan* A feature worthy of note is that usually the
various veins of the dorsal fan run practically parallel to
those of the ventral fan The latter arise, as it were at the
same spot from the distal end of the right paramedian vein Only
rarely are there branches of the dorsal fan situated posteriorly
to such an extent that they prove to arise at or proximal to the
origin of the vena paramedialis dextra such in contrast to the
branches of arteries and bile ducts as will be shown in the
next chapter

The cranial group of veins preponderate over those of the
caudal group The arborization of the ventral fan is sharply
marked off from that of the dorsal fan by the fissura intermedia
(figs 12 13 and 14)

The right portal vein trunk distally to the point of origin of
the right paramedian vein is called *vena dextra* this branch
runs close to the dorsal liver surface

Usually one single branch distal to the origin of the ramus
paramedialis dexter at a distance ranging from a few milli
metres to 2 cm or sometimes two distinct separate branches

arises from the inferior aspect of the vena dextra, running in a caudal direction to the right of the lateral fossa cystica: will *vena paracystica*. The area of ramification of this vein forms that part of the lobus dexter adjacent to the fossa cystica.

The ramus dexter divides into two branches, one to the segmentum dextro craniale, the *vena dextro-cranialis* or vena cranialis lobi dextri, and one to the segmentum dextro caudale, the *vena dextro caudalis* or vena caudalis lobi dextri. Several small branches, or one large one, originate from the vena dextro caudalis right at, or slightly distal to, the site of bifurcation of the vena dextra, running towards the right liver margin: the *vena dextro marginalis*.

A number of minor branches supply the lobus paramedialis dexter dorsalis.

Inside the liver the portal vein serves as carrier and guides the hepatic arteries and bile ducts. These arteries and bile ducts adhere to these veins just like vines climbing along a pole. Because these structures take a similar intrahepatic course to the portal vein branches supplying or draining the same sectors as distinguished for the ramifications of the portal vein, the arteries and bile ducts are given names identical to the corresponding branches of the portal vein, *e.g.*, vena paramedialis dextra, arteria paramedialis dextra, ductus paramedialis dexter (fig. 29 and 30).

As noted previously, the proper hepatic artery is situated on the medial side of the portal vein. After its bifurcation into a left and right branch, the left hepatic artery runs caudally to the portal vein; small arteries arise from its trunk running into the caudate lobe. Usually there is one, but occasionally there are several branches to the left paramedian lobe. In the fossa umbilicalis the left hepatic artery divides into a cranial branch to the segmentum cranio dorsale lobi sinistri, and a caudal one to the segmentum ventro caudale lobi sinistri. The right hepatic artery gives off the cystic artery and just before



Fig 9 The three structures of the Glissonian system (intrahepatically) 1 bile duct hepatic artery 3 portal vein



Fig 30 Dorsal aspect of specimen in which bile ducts (white) and left hepatic artery (dark) are injected

entering the body of the liver, or at the right margin of the porta hepatis, it usually bifurcates into two branches, one directed latero cranially, the arteria (lobi) dextri, and the other directed latero caudally, the arteria paramedialis dextra

The pattern of division of the *bile ducts* is generally fairly similar to that of the arteries The left hepatic duct is composed of a ductus cranialis lobi sinistri, originating in the dorso cranial left lobar segment, which joins the ductus caudalis lobi sinistri ventral to the curvature of the left portal vein, receiving one duct from the left paramedian lobe and 2–3 ductules from the caudate lobe The right hepatic duct is usually composed of two bile ducts The first drains the right lobe and is formed by the confluence of the dextro cranial and dextro caudal ducts, which together form the right lobar duct The second drains the right paramedian lobe They unite at the hilum, usually outside the body of the right liver at the right margin of the porta hepatis After its junction the right hepatic duct receives a variable number of minor branches from the caudate lobe and then joins the left hepatic duct, thus forming the main hepatic duct After its junction with the cystic duct it is called the common bile duct or ductus choledochus, which is located laterally to the portal vein

In concluding this chapter we can say on the basis of a comparative study of the hilar dissection with the injection corrosion specimens, that the two Glissonian pedicles, which can be identified in the former in the right hilar area, are identical with the right paramedian lobar and right lobar structures

Moreover the Glissonian pedicles which can be dissected in the left hilar area, as well as the umbilical fossa, are identical with the different segmental structures of the segments previously described

Every lobar or segmental pedicle can be dissected in the left hilar area and the umbilical fossa except that for the ventro cranial part of the left paramedian lobe

Chapter IV

VARIATIONS IN THE STRUCTURES OF THE GLISSONIAN SYSTEM

The first part of this chapter will be concerned with the variations which occur in the structures of the Glissonian system outside the liver, and more especially with those found at the *hilum of the liver*. *Wherever possible, our findings will be* collated with the data published in the literature, but this has not always been feasible on account of the fact that in some respects we have found it necessary to depart from the conventional approach to the matter, mainly because, in the preceding section, we adopted a certain classification and nomenclature not wholly identical with those used by other investigators, notably Healey *et al.* and Couinaud. This is not to say that we are less aware than they of the importance of these variations to surgery and that they are undoubtedly factors to be reckoned with in surgical intervention.

The variations of the different structures will be dealt with *systematically for each individual structure*, our aim being to define certain patterns into which the various structures fall at the hilum of the liver in relation to the lobes and segments drained or supplied by them.

Blood is discharged from the stomach, pancreas, intestines and spleen into the *portal vein*, which is composed of the following vessels.

The *vena coronaria sinistra*, which runs alongside the lesser curvature of the stomach near the arteria gastrica sinistra. As

demonstrated by Douglass *et al* and Gilfillan in their dissections (both in 1950), this vessel may discharge into the vena lienalis (58 9%) the vena portae communis (24 4%) or the vena mesenterica superior (16 7%) In the first mentioned case this vessel enters the vena lienalis at the site of the latter's discharge into the vena portae (All these and subsequent figures are cited from Douglass *et al*, 1950)

The *vena mesenterica magna sive superior*, which drains the blood from the region served by the arteria mesenterica superior into the vena portae This vein is composed of the vena pancreatico-duodenalis the vena gastro-epiploica dextra, the vena ileo colica, the vena colica dextra and the vena colica media Here too variations are liable to occur Thus Douglass *et al* found a vena pancreatico duodenalis in their series which consisted of a single vessel discharging into the vena portae communis (38%) or of several vessels with one or more discharging into the vena portae and the others into the vena mesenterica superior They sometimes saw the vena gastro-epiploica discharging into the vena portae (2 2%) or else into the vena lienalis (2 2%)

The *vena lienalis* which drains the blood from the stomach via the coronary vein in only 16 7% of dissections They also found that in 38% of the cases the vena mesenterica inferior discharged into this vessel

The *vena mesenterica parva sive inferior* which drains the blood from the region supplied by the arteria mesenterica inferior and which is connected with the vena hypogastrica via the vena haemorrhoidalis superior via the plexus haemorrhoidalis The vena mesenterica inferior usually enters the medial one third of the splenic vein but may enter the superior mesenteric vein In 38% of their dissections Douglass *et al* saw this vessel discharging into the vena lienalis in 29 3% of the cases into the vena mesenterica superior and in 32 7% together with the vena lienalis and the vena mesenterica superior, into the vena portae communis

On the evidence of the above figures it is clear that the site of entry of the many branches of which the vena portae is composed varies considerably

Glenard (1890) believed that blood is supplied to various areas of the liver from certain sections of the spleen gall bladder pancreas and gastro-intestinal tract In his view the left half of the liver receives blood from the spleen stomach duodenum colon descendens sigmoid and pancreas the right half of the liver being supplied from the remainder of large and small guts Serége (1901) Copher and Dick (1928) and Mermans (1946) explained this feature on the basis of the different separate blood currents present side by side in the portal vein The localization of pathology in the liver of an infectious or malignant nature transmitted to the liver from those organs which drain their blood via the portal vein has been linked with this stream lined effect of the portal vein blood There are examples *in pathology which illustrate the fact that predictions as to where a* secondary lesion will be manifested in the liver are exceedingly precarious Hence seen in this light the above variations acquire a clinical significance *as well and show yet again why it is often impossible to make any* such prediction (see Chapter VII)

The venous collateral circulation of the liver is far less extensive than what is generally regarded as the arterial collateral circulation, as will presently appear As far as the collateral circulation is concerned, we found anastomoses between the intrahepatic branches of the portal vein and the subserosal tiny vessels of the gall bladder It was also possible to demonstrate anastomoses with the venous channels of the diaphragm by way of the triangular and coronary ligaments

As a rule, there is little variation to be seen in the distribution of the vena portae at the hilum of the liver The most important *exception has already been noted by Rex, i.e.* that of the origin of the vena paramedialis dextra In the majority of mammalian livers this vessel was found to arise from the truncus sinister venae portae, usually *from the right trunk* in human livers, but sometimes this vessel arose exactly at the *bifurcation of the venae portae communis* Of 30 specimens dissected by Deve (1907) 22 showed this vessel deriving from the right trunk, 3 from the left and 5 from the bifurcation

We found the following percentages in our specimens *In*

70% this vessel proved to derive from the right trunk, in 10% from the left and in 20% from the bifurcation.

Let us now consider other variations which are liable to occur at the hilum.

In the case of the *fossa umbilicalis* it has been found that it is not possible to dissect every individual branch of the portal vein here. The branches which arise on the medial and lateral side of the saccus, are not invariably the only vessels supplying the areas on either side of the saccus. Some of them, varying in number, also arise at the ventral, ventro lateral and ventro-medial surface of this structure.

As we hope to show in the second part of this chapter, the vessels supplying the cranial section of the left lobus paramedialis* can seldom be dissected in the fossa, as these likewise arise in the ventral aspect of the pars sagittalis venae portae sinistrae.

We have also, though more rarely, come across a curious variation, i.e. that of the vena cranialis lobi sinistri arising at the same level as the vena caudalis lobi sinistri. In fact we once found the former branch deriving from the latter, though still within the region of the fossa umbilicalis!

As to the *right hilum* it may be said that in almost all livers in which the vena paramedialis dextra derives from the truncus dexter venae portae, this vessel can be visualized either in the hilum or in the incisura dextra after dissection.

The procedure to be adopted in the event of the absence of the incisura dextra will be discussed in Chapter VIII.

The vena paramedialis dextra usually runs caudo ventrally in fresh livers. Often the vena paracystica, which commonly arises somewhat more distally, cannot be visualized in this way.

Not only do variations occur at the site of origin of the *hepatic artery*, but also in the number of arterial branches sup

* When we speak of the lobus paramedialis we mean the ventral lobes; our references to the Glissonian territories of the caudate lobe are qualified by the adjective dorsalis.

plying the liver as well as the site of division of the proper hepatic artery

Von Haller (1764) and Hyrtl (1873) pointed out that injection of the aorta, following ligation of the proper hepatic artery in the hepato duodenal ligament, resulted in a filling of a great number of minor arterial branches running to the liver These branches were called "arteriae hepaticae accessoriae" Initially all these vessels were considered as arterial "collaterals' They were seen to arise from the aorta, superior mesenteric artery, left gastric artery, right renal or spermatic artery, right phrenic artery, internal mammary artery, pericardiophrenic artery, inferior epigastric artery, etc (Henle, 1864)

Von Haller even thought that the arteria hepatica accessoria ex mesenterica was always present "perpetua arteria est, quae ex mesenterico trunco omnium prima (ad hepar) prodit", ("there is always an artery present which arises from the mesenteric artery and goes to the liver'), which was partly refuted by Hyrtl's observation in 20 injected cadavers of infants, where he found this artery to be present thirteen times The occurrence of the other accessory arteries was even less frequently observed

Hyrtl also observed that occasionally the accessory hepatic artery may develop to such an extent 'dass sie normale Aeste der Leberarterie uberflussig machen und ganzlich verdrangen' (" that they make the normal branches of the hepatic artery superfluous and completely displace them) This is readily comprehensible from the ontogenetic standpoint Hence this vessel is an "aberrant hepatic artery

In over 230 cadavers Rio Branco (1912) found the existence of *one single* hepatic artery in 59%, arising in 55% of cases from the celiac artery and in 4% from the superior mesenteric artery Occasionally the right and left rami arise separately from the various upper abdominal arteries, such as superior mesenteric artery or left gastric artery Rio Branco traced the site of origin in the case of a *double* hepatic artery, which

occurred in 40% of his dissections, and found a right branch arising from the superior mesenteric artery in 10%, a left branch arising from the left gastric artery in 10%, a reduplication of the proper hepatic artery in 20% of his dissections

Henle (1864) described cases with *three* separate hepatic arteries, one from the left gastric artery, the second from the coeliac artery, and the third from the superior mesenteric artery According to this author this variation would occur in a small percentage of all dissections, which was confirmed by Rio Branco who found three hepatic arteries in 2% of his dissections taking the same origin as described by Henle

The presence of these so called accessory hepatic arteries has also been described by Haberer (1905) He noted that their number, site of origin and course are variable These vessels occurred in 32% of 75 dissection specimens which were at his disposal, sites of origin mentioned are those previously mentioned by Von Haller aorta superior mesenteric artery, left gastric artery, right renal or spermatic artery etc etc

In our casts we were able to confirm the observation made by Hyrtl (1873) and Healey *et al* (1953) that these accessory or replacing arteries *do not supply areas already receiving blood from the proper or the aberrant hepatic artery* These accessory hepatic arteries which enter the liver at the porta hepatis, umbilical fossa or occasionally at the dorsal surface of the organ without entering the hilum namely by way of adhesions between the liver and the hepato-duodenal ligament, the coronary and hepato renal ligaments are therefore endarteries in the sense originally described by Cohnheim (1876) and do not serve as collaterals in cases of occlusion of the proper hepatic artery (Hyrtl, 1873, Haberer, 1905 Healey *et al* 1953)

As regards the hepatic arteries anastomoses were occasionally observed in the umbilical fossa between the arteria paramedialis sinistra and the arteria caudalis lobi sinistri usually ventrally to the saccus or the pars sagittalis venae portae

Segall (1923) described numerous anastomoses between the

intrahepatic branches of the hepatic artery and the phrenic artery. These shunts, first observed by Cruveilhier (1867), which pass via the ligamenta triangulare et coronaria to the liver and anastomose with the arterial vessels in the capsule of the liver, are vessels of the 6th–7th order of subdivision. In *contrast to the accessory artery, it has been reported that, after occlusion of the proper hepatic artery, these vessels, serving as* collateral channels, can maintain a compensatory arterial circulation (Haberer, 1905) after an initial period of a week to *ten days (Segall, 1923, Markowitz, 1949).*

In the hepato duodenal ligament, the proper hepatic artery is situated on the medial side of the common duct, overlying the portal vein. Dissection specimens show a variable point of division into right and left hepatic artery. In most of the specimens the bifurcation is in the porta hepatis near the border of the quadrate lobe. Segall (1923), who investigated the location of the bifurcation of the proper into right and left hepatic artery, found the point of division at the former site to be present in 40% of his 55 dissections. In Healey's as well as our specimens the bifurcation in this area is always situated to the left of the main fissure. In *about 35% of Segall's specimens* the bifurcation was present between porta hepatis and inferior margin of the quadrate lobe, and in about 25% at a variable point between inferior liver margin and coeliac axis.

Both right and left hepatic artery usually subdivide into two or more branches at the hilum. Descomps and Laloubie (1910) gave the following percentages for the different numbers of branches, which were visualized at the hilum in 50 dissections.

right hepatic artery		left hepatic artery	
1 branch	4%	1 branch	22%
2 branches	26%	2 branches	36%
3	42%		
4	16%	4	12%
5	6%	5	8%

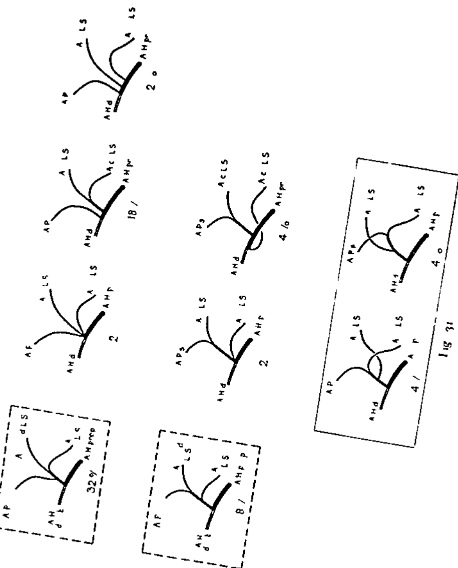


Fig 31

The *arteria hepatica sinistra* may divide in a number of ways. Among the fifty corrosion specimens in which we studied the variations presented, we found nine patterns where the left hepatic artery *divided in the hilum (fig. 31)*.

The pattern usually encountered in our specimens is consistent with the situation as represented in fig. 32. The left hepatic artery is directed medially, overlying the pars transversalis venae portae sinistrae, and is the first structure encountered during the left hilar dissection. It gives off a branch (diameter of the lumen 2–3 mm.) for the left paramedian lobe, *i.e.*, the left paramedian artery, which can be followed extrahepatically to the umbilical fossa as it runs along the medial surface of the sagittal part of the left portal vein trunk. Between the origin and the site of entry into the liver of this vessel, it *throws out* a branch, usually at the level of the curvature of the left portal vein trunk; this, running in a central cranial direction, almost immediately disappears into the body of liver tissue, joining the left paramedian cranial vein (see pg. 88). It supplies the cranial part of the *left paramedian lobe with arterial blood. The sagittal* arterial branch, running along the medial surface of the pars sagittalis venae portae sinistrae, joins the corresponding vein arising from the medial aspect of the saccus before entering the body of liver tissue, after which these structures continue their intrahepatic course in close *proximity*. Distally

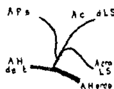
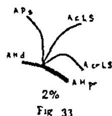


Fig. 32

to the origin of the left paramedian artery, the left hepatic artery, usually in the umbilical fossa, occasionally medial to or otherwise *dorsal to the portal vein divides into two branches*, which pass either over or laterally to the pars sagittalis. These two branches, the cranial and caudal left lobar arteries, join the corresponding veins arising from the lateral aspect, at the curvature and at the saccus of the pars sagittalis before entering the left liver lobe, *thus can be visualized by incising the* capsule along the left liver lobe (see fig. 25).

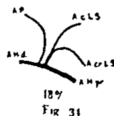
The venae craniales et caudales lobi sinistri come into view at the site where these vessels arise from the pars sagittalis venae portae, and are accompanied by the arterial branches

A modification of this condition is shown in fig 33, where no distinct left hepatic artery appears to be present Instead of this vessel, three arterial branches arise at the same level from the proper hepatic artery, which together supply the hepar sinister These branches are the arteria paramedialis ventralis sinister the arteria cranialis and the arteria caudalis lobi sinistri (2%)



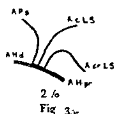
2%
Fig 33

Another recurrent variation of the normal pattern, which was encountered in 18% of the corrosion specimens (Healey *et al* 25%), is represented by fig 34 The left hepatic artery alone supplies the lobus sinister, this vessel is broken up into an arteria cranialis and an arteria caudalis lobi sinistri The arteria paramedialis sinistra originates distally to the site of origin of the left hepatic artery or left lobar artery, as the case may be, and therefore ought to be regarded as arising from the right hepatic artery



18%
Fig 34

A modification of this condition appears in fig 35 Apparently there is no distinct left hepatic artery All three branches arise separately from the proper hepatic artery (2%)



2%
Fig 35

The other extreme as represented by fig 36 shows that the left paramedian artery is a branch of the most distal part of the left hepatic artery which bifurcates at the level of the saccus into an arteria caudalis lobi sinistri and an arteria paramedialis sinistra The arteria cranialis lobi sinistri originates at a more proximal point from the left hepatic artery (8%) (Healey *et al* 35%)

The *arteria hepatica sinistra* may divide in a number of ways. Among the fifty corrosion specimens in which we studied the variations presented, we found nine patterns where the left hepatic artery divided in the hilum (fig. 31).

The pattern usually encountered in our specimens is consistent with the situation as represented in fig. 32. The left hepatic artery is directed medially, overlying the pars transversalis venae portae sinistrae, and is the first structure encountered during the left hilar dissection. It gives off a branch (diameter of the lumen 2–3 mm.) for the left paramedian lobe, *i.e.*, the left paramedian artery, which can be followed extrahepatically to the umbilical fossa as it runs along the medial surface of the sagittal part of the left portal vein trunk. Between the origin and the site of entry into the liver of this vessel, it throws out a branch, usually at the level of the curvature of the left portal vein trunk; this, running in a central cranial direction, almost immediately disappears into the body of liver tissue, joining the left paramedian cranial vein (see pg. 88). It supplies the cranial part of the left paramedian lobe with arterial blood. The sagittal arterial branch, running along the medial surface of the pars sagittalis venae portae sinistrae, joins the corresponding vein arising from the medial aspect of the saccus before entering the body of liver tissue, after which these structures continue their intrahepatic course in close proximity. Distally

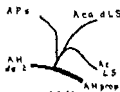


Fig. 32

to the origin of the left paramedian artery, the left hepatic artery, usually in the umbilical fossa, occasionally medial to or otherwise dorsal to the portal vein, divides into two branches which pass either over or laterally to the pars sagittalis. These two branches, the cranial and caudal left lobar arteries, join the corresponding veins arising from the lateral aspect, at the curvature and at the saccus of the pars sagittalis before entering the left liver lobe; this can be visualized by incising the capsule along the left liver lobe (see fig. 25).

The venae craniales et caudales lobi sinistri come into view at the site where these vessels arise from the pars sagittalis venae portae, and are accompanied by the arterial branches

A modification of this condition is shown in fig 33 where no distinct left hepatic artery appears to be present Instead of this vessel, three arterial branches arise at the same level from the proper hepatic artery, which together supply the hepar sinister These branches are the arteria paramedialis ventralis sinister, the arteria cranialis and the arteria caudalis lobi sinistri (2%)

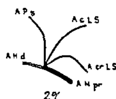


Fig 33

Another recurrent variation of the normal pattern, which was encountered in 18% of the corrosion specimens (Healey *et al* 25%), is represented by fig 34 The left hepatic artery alone supplies the lobus sinister this vessel is broken up into an arteria cranialis and an arteria caudalis lobi sinistri The arteria paramedialis sinistra originates distally to the site of origin of the left hepatic artery or left lobar artery, as the case may be, and therefore ought to be regarded as arising from the right hepatic artery

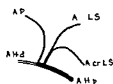


Fig 34

A modification of this condition appears in fig 35 Apparently there is no distinct left hepatic artery All three branches arise separately from the proper hepatic artery (2%)

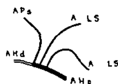


Fig 35

The other extreme as represented by fig 36 shows that the left paramedian artery is a branch of the most distal part of the left hepatic artery which bifurcates at the level of the saccus into an arteria caudalis lobi sinistri and an arteria paramedialis sinistra The arteria cranialis lobi sinistri originates at a more proximal point from the left hepatic artery (8%) (Healey *et al* 35%)

The *arteria hepatica sinistra* may divide in a number of ways. Among the fifty corrosion specimens in which we studied the variations presented, we found nine patterns where the left hepatic artery divided in the hilum (fig 31).

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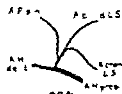


Fig 3

The venae craniales et caudales lobi sinistri come into view at the site where these vessels arise from the pars sagittalis venae portae, and are accompanied by the arterial branches

A modification of this condition is shown in fig 33 where no distinct left hepatic artery appears to be present Instead of this vessel, three arterial branches arise at the same level from the proper hepatic artery, which together supply the hepar sinister These branches are the arteria paramedialis ventralis sinister, the arteria cranialis and the arteria caudalis lobi sinistri (2%)

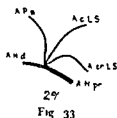


Fig 33

Another recurrent variation of the normal pattern, which was encountered in 18% of the corrosion specimens (Healey *et al* 25%) is represented by fig 34 The left hepatic artery alone supplies the lobus sinister, this vessel is broken up into an arteria cranialis and an arteria caudalis lobi sinistri The arteria paramedialis sinistra originates distally to the site of origin of the left hepatic artery, or left lobar artery, as the case may be, and therefore ought to be regarded as arising from the right hepatic artery

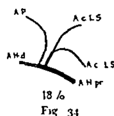


Fig 34

A modification of this condition appears in fig 35 Apparently, there is no distinct left hepatic artery All three branches arise separately from the proper hepatic artery (2%)

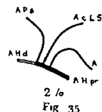


Fig 35

The other extreme as represented by fig 36 shows that the left paramedian artery is a branch of the most distal part of the left hepatic artery which bifurcates at the level of the saccus into an arteria caudalis lobi sinistri and an arteria paramedialis sinistra The arteria cranialis lobi sinistri originates at a more proximal point from the left hepatic artery (8%) (Healey *et al* 35%)

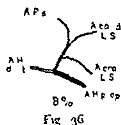
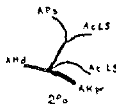

8%

Fig 36

From the modification represented in fig 37 it appears that the latter may even arise from the proper hepatic artery (2%) A modification of this condition is represented by fig 38 Here the arteria hepatica sinistra supplies the left paramedian lobe and the ventro caudal segment of the left liver lobe The cranial segment artery arises from the right hepatic artery (4%)

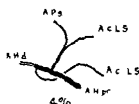
Two rather unusual variations are reproduced in figs 39 and 40, the arteria caudalis lobi sinistri arises proximal to the arteria cranialis (4%) (see fig 39) and in fig 40 the arteria paramedialis sinistra arises from the arteria cranialis lobi sinistri (4%)



2%

Fig 37

Together these variations represent 76% of our corrosion specimens In the other 24%, regions normally supplied by



4%

Fig 38

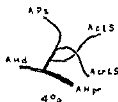

4%

Fig 39

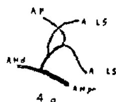

4%

Fig 40

the left hepatic artery did not fill probably on account of the fact that these areas were supplied by accessory hepatic arteries

In 14% of the specimens the arterial bed of the hepar sinister did not fill up in 8% the arteries of the left lobe were not filled in 2% the arteries of the left paramedian lobe remained empty (fig 41)

Several patterns of ramifications of the *right hepatic artery* can

as a rule be observed at the hilum In 86% of the specimens the arterial branches are located dorsally to the bile ducts (Healey 87%) and appear as the first structures during hilar dissection In 8% of the specimens (Healey 11%) they passed in front of the ducts In 6% of the specimens it was impossible to tell definitely whether they were situated dorsally or ventrally relative to the bile ducts Distally to the division of the right hepatic artery the different arterial branches join the corresponding veins In at least 22% of the specimens the right hepatic artery divided into more than two branches at the hilum however we could not ascertain definitely in our

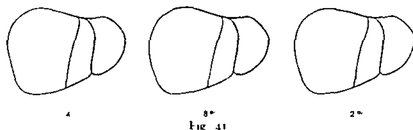


Fig 41

casts whether a further division took place at the hilum or intrahepatically For this reason we assume that the further divisions take place intrahepatically

We distinguish three basic patterns for the division of the right hepatic artery *viz* the first characterized by an artery which without dividing penetrates into the right half of the liver the second characterized by the division of the right hepatic artery into a right paramedian artery directed caudo laterally and a right artery directed cranio laterally finally the third which represents the reverse of the second group in that the caudal branch is the arteria dextra instead of the arteria paramedialis dextra while the cranial branch runs towards the right paramedian lobe[1] (fig 42)

The first pattern is characterized by the fact that the right hepatic artery enters the liver undivided (8%) (fig 43)

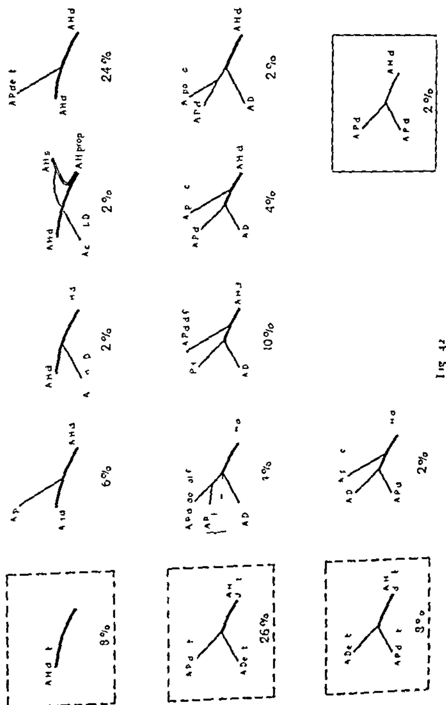


Fig 42

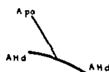
Frequently a minor branch arises from the right hepatic artery, but it appears to be a segmental instead of a lobar arterial trunk

This pattern was encountered as such in 34% of the specimens In 10% of the specimens the minor branch appeared to supply one of the segments of the lobus dexter *viz*, in 6% the caudal segment (fig 44) or a part of this segment (or else ramifications of the vena paracystica) and in 2% the cranial segment (fig 45) In 2% of the specimens the right hepatic artery without dividing at the hilum supplied the whole



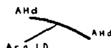
8%

Fig 43



6%

Fig 44

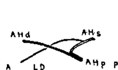


2%

Fig 45

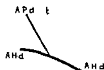
right half of the liver minus the cranial segment of the right lobe which received arterial blood from the left hepatic artery (fig 46)

In 24% of the specimens (fig 47) a minor branch was seen arising from the right hepatic artery supplying different areas of the right paramedian lobe, in the majority of specimens this branch had a considerable calibre and supplied the right paramedian lobe almost completely



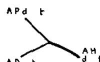
2 /

Fig 46



24 /o

Fig 47



26 /o

Fig 48

All the variations of the second group have one feature in common namely that the right hepatic artery divides right at the

hilum into an artery directed caudo laterally, running to the right paramedian lobe, and another artery, directed cranio-laterally, running into the lobus dexter

The total number of specimens in which we met this condition was 46% (Healey 52%) This condition, without any further variations, was encountered in 26% of the specimens (fig 48)

In 4%, a trifurcation instead of a bifurcation of the right hepatic artery was found (fig 49) The branch directed most caudally appeared to be the arterial branch supplying the 'dorsal fan' area, the middle branch supplied the 'ventral fan' area of the lobus paramedialis dexter, the cranial branch supplied the lobus dexter

In 10% of the specimens (fig 50) an arterial branch supplying the 'dorsal fan' area of the lobus paramedialis dexter arose even proximal to the site of the bifurcation of the right hepatic artery

In 4% of the specimens (fig 51) a branch supplying part of

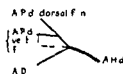


Fig 49

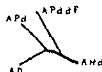


Fig 50

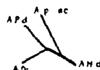


Fig 51

the caudal segment of the lobus dexter, namely the area para cystica was seen to arise proximally to the bifurcation of the right hepatic artery in 2% of the specimens (fig 52) from the arteria paramedialis dextra

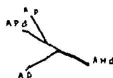


Fig 52

A third group of variations though a minor one considering the number of cases encountered, showed the reverse pattern of the second group the caudo lateral arterial branch, distal

to the bifurcation of the right hepatic artery, appeared to be the arteria dextra, instead of the arteria para medialis dextra (10%) (fig 53 and 54) In 2% of the specimens a small artery was seen to arise proximal to the bifurcation of the right hepatic artery supplying the area of ramification of the vena para cystica (fig 54)

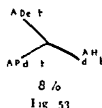


Fig 53

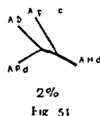


Fig 54

In only one specimen did we find the lobus dexter supplied by an aberrant hepatic artery[1] (fig 55)

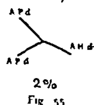


Fig 55

While studying the literature, both Hyrtl and Rex were struck by the great number of variations occurring in the ramifications of *bile ducts* in mammalian livers, which at that time accounted for a confusion in this field throwing Hyrtl into such despair that he wrote Man verliert allen Bucher glauben und alles Vertrauen auf den Werth von Citaten wenn man auf solche Unrichtigkeiten stosst Rex noted the cause of this confusion Diese Verwirrung beruht lediglich in dem einem Umstande dass soviel ich ersehe, meist nur ein Thier dem Untersucher vorgelegen, dass ferner aus dem Grunde dass man sich mit einem gewonnenen Bilde begnugte auch die Erkenntniss der mannigfachen Variabilitat der Verastlung der Gallenwege versagt bleibt (This confusion rests entirely on the fact that as far as I can see most of the research has been done one animal, and further on the fact that the research workers were content with the conception they had formed of it This has made it impossible to acquire a knowledge of the great variability of bile duct ramifications) To a certain extent the same applies to the division of the bile ducts of the human liver

Rex inferred the existence of three hepatic ducts from his

corrosion specimens, *viz.*, a right, left and middle duct.

Among those who have studied the topography of the bile ducts were E. Ruge (1909) in 43 and Johnson and Anson (1952) in 35 livers from which the hilum was dissected. Ruge found a ductus hepaticus communis in 32 specimens arising from a right and left hepatic duct. In 5 specimens he found the ductus hepaticus communis deriving from three, and three times from five hepatic ducts. He also reported the absence of any ductus hepaticus communis at all in three specimens owing to the fact that the cystic duct discharged into the right hepatic duct. Ruge further noted that, where the ductus hepaticus medius was present, it often issued from the quadrate lobe (namely, in five of the nine cases!).

In 35 livers Johnson and Anson (1952) found that one to two ducts 'joined the point of confluence of the main left and right ducts' in five specimens. These tributaries proved to be of far thinner calibre than the "main ducts". A further comment was that the bile ducts are the most ventrally situated structures as a rule in the hilum, and are by no means easy to dissect.

Extrahepatic bile ducts have been described at other sites besides the hilum, *viz.*, the so called aberrant ducts (Ferrein, 1753; Kiernan, 1833). They are most frequently found in the connective tissue round the inferior vena cava, the coronary ligament, the left cranial margin of the liver, in the umbilical fossa and the hepatogastric ligament. It is possible that ducts of Luschka (Raport & Hromada, 1950) are such "aberrant" hepatic ducts. They communicate with the intrahepatic duct system and may be opened during upper abdominal surgery.

Raport *et al.* reported two instances in which vagotomy was complicated by cholerrhagia due to opening of one of these ducts. They are absent in the foetus and child, their number increasing with advancing age. Raport *et al.* regard these ducts as intrahepatic ducts which have been preserved following reduction or atrophy of liver tissue and have thus become extrahepatic.

of the hepatic ducts

The variations at the site of discharge of the hepatic ducts coming from the *left half* of the liver were classified in six groups for the fifty corrosion specimens which we studied. It must be emphasized yet again that we are now dealing with findings in the corrosion specimen, as dissection of the bile ducts at the hilum is a major problem[1] (fig. 56).

The most recurrent feature is represented in fig. 57. Two ducts can be recognized leaving the lobus sinister at the same

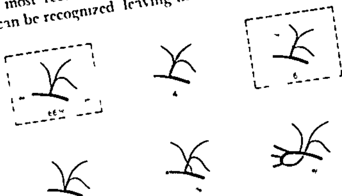


Fig. 56

sites where both segmental veins and arteries enter this lobe. The bile ducts which are the most ventrally located structures at the hilum run anteriorly, *viz.* ventrally to the vein and artery. In the fossa umbilicalis the ductus caudalis lobi sinistri runs laterally to the pars sagittalis venae portae and joins the ductus cranialis lobi sinistri ventrally to the bend of the left portal vein trunk, the common duct of the left lobe joins the paramedian duct in the hilum. The ductus paramedialis sinister leaves the lobe at the site where vein and artery enter their territory at the medial side of the saccus. During its course along the medio-ventral surface of the pars sagittalis venae portae, a branch from the cranial territory of the lobe joins this duct.

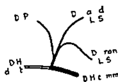


Fig. 57

We found this condition in 66% of our specimens, Healey *et al* in 67% of his casts Occasionally, bile ducts were seen to cross over between the segmentum caudalis lobi sinistri and the caudal area of the left paramedian lobe

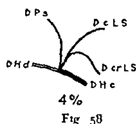


Fig 58

A union of all three ducts at one site was found in 4% of our specimens (fig 58)

A union of the ductus paramedialis sinister and ductus caudalis lobi sinistri takes *place at the level of the saccus in* 16% of our specimens (Healey *et al* 25%) (fig 59)

A union of the ductus lobi sinistri and ductus paramedialis sinister at the site of junction with the right hepatic duct occurs in 4% of the specimens (fig 60)

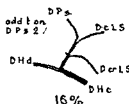


Fig 59



Fig 60

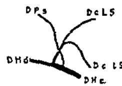


Fig 61

The presence of the left hepatic duct was not definitely established in *8% of our specimens*

It appears that the ductus lobi sinistri enters the common hepatic duct proximal to the ductus paramedialis sinister in 4% (fig 61) In 4% of the specimens the different bile ducts from the right liver half enter the ductus lobi sinistri before joining *the left paramedian duct (fig 62)*



Fig 62

The variations at the site of discharge of the hepatic ducts coming from the *right half* of the liver were arranged in three groups, each of which was subdivided

In the first of these three groups the right hepatic duct is composed of a cranial right duct and a caudal right paramedian duct, in the second group the arrangement is precisely reversed and in the third the junction of the two lobar ducts has already taken place intrahepatically (fig 63)

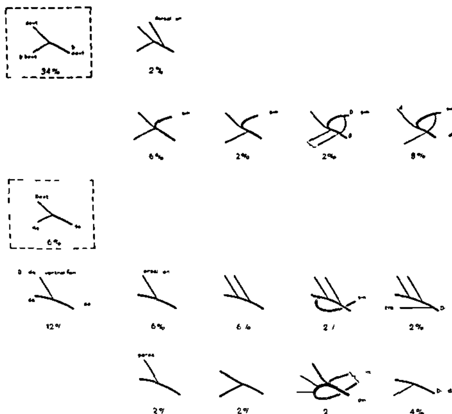
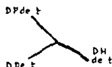


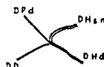
Fig 63

In 54% of the specimens the right hepatic duct is composed of the two lobar ducts viz that cranially located from the *lobus dexter and the caudal duct from the lobus paramedialis* dexter The condition without any further variations was encountered in 34% of the specimens (fig 64) In 6% of the

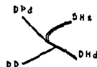
specimens these two ducts unite with the left hepatic duct forming the common hepatic duct (fig 65)

In 2% of the specimens the ductus dexter enters the common hepatic duct, hence there is no right hepatic duct The ductus paramedialis dexter joins the left hepatic duct (fig 66)


34%
Fig 64



6%
Fig 65



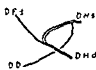
2%
Fig 66

Moreover, in one specimen the bile of the cranial segment of the lobus dexter is discharged into the left hepatic duct[1] (fig 67)

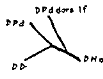
In 8% of the specimens, *likewise without the right hepatic* duct, the ductus paramedialis dexter joins the left hepatic duct to form the common hepatic duct, while the ductus dexter enters the left hepatic duct (fig 68) In one instance a duct



2%
Fig 67



8%
Fig 68



2%
Fig 69

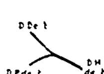
from the dorsal fan area joined the right hepatic duct distally to the point of junction of both lobar ducts (fig 69)

A second pattern, in which the ductus dexter is located caudally to the ductus paramedialis dexter is only seen in 6% of the specimens (fig 70)

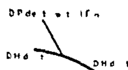
A third pattern, encountered in 38%, of our specimens is that in which it proves difficult to visualize both lobar ducts at the hilum its junction therefore is considered to be intrahepatically The right hepatic duct leaves the liver at the

right hilar margin. Segmental or territorial branches may join the right hepatic duct extrahepatically.

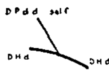
In 12% of our specimens a duct can be recognized joining



6%
Fig. 70



12%
Fig. 71



6%
Fig. 72

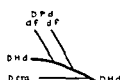
the right hepatic duct which drains the ventral fan area (fig. 71), in 6% a distinct separate duct drains the dorsal fan area (fig. 72). In 6% of the specimens two ducts can be visualized



6%
Fig. 73

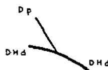


2%
Fig. 74

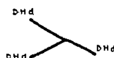


2%
Fig. 75

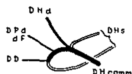
entering the right hepatic duct at the hilum, the proximal one from the ventral fan area of the right paramedian lobe, the distal one from the dorsal fan area (fig. 73).



2%
Fig. 76



2%
Fig. 77



2%
Fig. 78

In 2% of the casts these two ducts join the common hepatic instead of the right hepatic duct (fig. 74).

In another 2% two ducts from the dorsal fan area and one

duct from the segmentum craniale lobi dextri join the right hepatic duct (fig 75)

In 2% one duct drains the area paracystica (fig 76), while in another specimen two ducts on the right join extrahepatically, both draining areas from both lobes (fig 77) *Moreover in 2% a ductus dexter* and a duct from the dorsal fan area separately enter the left hepatic duct (fig 78), and in 4% the ductus dexter joins the right hepatic duct (fig 79)

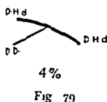


Fig 79

Up to the present, we have been concerned solely with variations that are to be observed at the *hilum* of the liver and it will have become clear that the extent to which the ramifications of the various structures of the Glissonian system can be followed in the left hilum is far greater than in the right hilum Accordingly, *we had no difficulty in discovering how all the lobes* and segments are arterially supplied in the *left* half of the liver and how these areas drain their bile, with one exception, *viz.*, the ventro cranial region of the left paramedian lobe *The* various structures of the Glissonian system at the hilum cannot be rendered visible in this part of the liver as they can in the rest of the left liver

We have already ascertained in the *right* half of the liver that the vena paramedialis dextra and the vena dextra can be dissected at the hilum or its extension the incisura dextra As a rule the corresponding artery and bile duct run along the *medial side of the right paramedian vein*, but this vessel may be accompanied by several arteries and bile ducts, supplying or draining different areas of the right paramedian lobe It is then found that *these arteries and bile ducts are usually placed* laterally and/or cranially and or caudally relative to the vein and either derive from or run to the right artery or right duct respectively[1]

Something similar occurs in a number of livers as regards the

distribution of the arteries and bile ducts supplying or draining the two segments of the right lobe Although the natural inference is that the two segments of the right hepatic lobe would be supplied with arterial blood from the right artery and would drain bile via the right duct into the right hepatic duct, apparently this is not an invariable rule

For this reason we shall touch briefly on these variations in a general way not dwelling on individual variations, as they do not readily lend themselves to systematic discussion and any such attempt would only lead to confusion

Lobus paramedialis sinister Cranial area

As has been stated the vena portae branches for the ventro cranial area of the left paramedian lobe cannot be visualized at the hilum This area is usually supplied by several branches (see fig 27, p 56) originating from the sagittal part of the portal vein generally from its ventral aspect There is pronounced anatomical resemblance between these venae paramediales sinistrae craniales and the cranial branches of the vena paramedialis dextra in the right half of the liver

In 25% of the specimens the site of origin of the main branch is at the ventral surface of the saccus in 35%, it is between saccus and curvature of the left portal vein trunk in 25% (28% according to Couinaud), at the cranial pole of the saccus ventralis and in 5% at the ventral surface of the curvature This vessel (or after its division into branches these vessels) runs (run) in a ventro cranial direction

In 35% of the specimens an additional branch is seen arising from the *medial surface of the sagittal part of the portal* vein on the cranial side of the vena paramedialis sinistra caudalis It curves ventrally and cranially into this segment in 4% of the cases it arises straight from the concave side of the bend running in a cranio ventral direction

Generally, one at least of the terminal branches of the venae paramediales sinistrae caudales is also directed cranially

As far as we can judge (for, to give exact percentages would necessitate analysing every liver), arterial supply often takes place from the left paramedian artery, though the area is sometimes supplied from the arteria caudalis lobi sinistri.

Bile is drained into the ductus paramedialis sinister, but we have found on several occasions that the bile duct runs straight to the adjacent duct formed ventrally to the curvatura trunci sinistri *venae portae from the junction of ductus caudalis and* ductus cranialis lobi sinistri.

Before proceeding to discuss the variations of the Glissonian system in the right half of the liver, we should make it plain that the division of the right paramedian lobe into a cranial and caudal area is an artificial one serving only to facilitate a systematic treatment of this matter.

Lobus paramedialis dexter Cranial area

Portal vein Apart from some minor individual variations, impossible to describe separately, this area is in general supplied by two to four major branches from the dorsal and, by the same number of major branches, from the ventral fan, their direction is cranial, cranio lateral and cranio medial.

Hepatic artery The arterial branches, which accompany the venous branches of the dorsal fan in this area originate in 80% of the cases from the arteria paramedialis dextra and in 18% from the arteria dextra, in 2% from the arteria hepatica dextra. As all arterial branches having a common course with the portal vein branches of the ventral fan arise from the arteria paramedialis dextra, we were able to compare our data with the percentages found by Healey *et al* in a large number of cases (70 cases). These authors found in 87% of their specimens that the cranial area of the right paramedian lobe was supplied by the arteria paramedialis dextra and in 10% by the arteria dextra. In one of their cases, the latter artery arises from the left hepatic artery.

Bile ducts The bile ducts accompanying the portal vein branches of the dorsal fan in this area empty in 78% of specimens into the ductus paramedialis dexter in 18%, one or more branches open into the ductus dexter and in 4%, one or more branches drain into the right hepatic or common hepatic duct The bile ducts corresponding with the portal vein branches of the ventral fan empty in 98% of the specimens into the ductus paramedialis dexter and in 2%, into the right hepatic duct

Lobus paramedialis dexter Caudal area

Portal vein The branches of the dorsal as well as of the ventral fan run in caudal, lateral and medial directions

Hepatic artery The arterial branches corresponding with the portal vein branches of the dorsal fan prove in 72% of the cases to originate from the arteria paramedialis dextra, in 22% from the arteria dextra and in 6% from the arteria hepatica dextra The arterial branches accompanying the branches of the ventral fan all arise from the arteria paramedialis dextra Healey *et al* found that the arterial supply of this segment was via the arteria paramedialis dextra in 86% of their cases and in 14% via the arteria dextra

Bile ducts The bile ducts corresponding in this area with the portal vein branches of the dorsal fan empty in 72% of the specimens into the ductus paramedialis dexter in 16% one or more branches from this area open into the ductus dexter and in 12% one or more branches drain into the ductus hepaticus These figures are for the branches of the ventral fan 98%, 2% and 0%

Lobus dexter

The vena dextra bends in a caudo lateral direction with a curvature ranging between 90 and 120° A major branch the vena cranialis lobi dextri arises right at the curvature running in a cranio lateral direction The terminal part of the vena

dextra (vena caudalis lobi dextri) gives off a number of vessels in a horizontal direction parallel to one another (*venae marginales*), their average number is four. A variable number of vessels in cranial or caudal direction, the venae intermediales, may be present between the origin of the vena paramedialis dextra and the curvature of the lateral vein. The usual number is only one, however. The vena intermedialis, adjacent to the right wall of the fossa cystica, has been named by us vena paracystica.

Segmentum craniale lobi dextri

(The figures between brackets denote the percentages found by Healey, Schroy & Sorensen.)

Hepatic arteries. In 86% of the specimens the cranio-lateral artery arises from the arteria lobi dextri (86%), in 6% (12%) from the arteria paramedialis dextra, in 6% (2%) directly from the arteria hepatica dextra, and in 2% from the arteria hepatica sinistra.

Bile ducts. In 100% of the cases of Healey *et al.* this area drains into the lateral duct. This is not confirmed in our specimens. In 88% of our cases drainage takes place into the ductus lobi dextri, in 6% into the ductus paramedialis dexter, in 2% into the ductus hepaticus dexter and in 4% into the ductus hepaticus sinister.

Segmentum caudalis lobi dextri

(The figures between brackets are those of Healey *et al.*)

Hepatic arteries. In the majority of cases, namely 92% (77%) the segmental artery arises from the arteria lobi dextri, in 0% (20%) it originates from the arteria paramedialis dextra and in 8% (3%) from the right hepatic artery.

Bile ducts. In 86% (86%) of the cases this segment drains into the ductus lobi dextri, in 8% (10%) into the ductus paramedialis dexter, in 4% (4%) into the right hepatic duct and in 2% into the common hepatic duct.

While we are well aware that the foregoing by no means covers all the variations liable to occur we do believe we have enumerated the most significant among them

Of the more erratic variations we might cite that described by Kehr (1912) i.e. that of a duct which he saw coming from the right half of the liver draining into the gall bladder or a more recent case reported by Norman (1950) of a bile duct deriving from the right half of the liver emptying into the ductus cysticus

If we had to generalise we might say that as a rule Nature repeats herself though the term freak of Nature witnesses to the fact that she is capable of some queer vagaries

Chapter V

THE HEPATIC VEIN SYSTEM AND ITS VARIATIONS

Up to the present, scant reference has been made to the second system of intrahepatic structures, which is composed of the hepatic veins. The arrangement of this system of veins is far less complicated than that of the Glissonian system, while the structures, themselves, are subject to comparatively few, mostly minor variations. We shall therefore devote this chapter to a consideration of these structures and the variations most commonly encountered.

As was noted previously, Glisson (1654) was the first to relate the ramifications of the portal and hepatic veins in the proper way, which appears from his two illustrations (figs. 4A and 4B, p. 10 and 11).

There are three major veins—initially called the "rami primarii venae cavae" (Glisson) but later renamed the venae hepaticae—and several minor hepatic veins, all of which enter the inferior vena cava. It will be necessary to have a clear picture in our minds of the location of the inferior vena cava in relation to the liver before we proceed to discuss the venae hepaticae, on account of their close connection with that vein.

The inferior vena cava is located in a more or less deep groove at the dorso-cranial surface of the liver, i.e. the sulcus or fossa pro venae cavae, situated in between the lobus caudatus on its left and the right liver lobe on its right. The vessel here runs in the bare liver area in between the two

leaves of the triangular ligament, namely the ligamentum hepato-diaphragmaticum on the ventral and the ligamentum hepato-renale on the dorsal side. A dorsal ligament, the ligamentum venae cavae, holds the vein in the fossa. If the ventral liver surface is turned cranially and the right liver lobe then rotated towards the mid line, the inferior vena cava presents itself against the dorsal wall of the abdominal cavity to the right and alongside the vertebral column, showing through the covering layer of mesentery, the so-called caval mesentery. On incision of the caval mesentery along this vein, the vessel comes into view (fig. 110c).

The groove of this vein is clearly visible upon inspection of the corrosion specimens of which the Glissonian system alone has been injected. Three openings are, moreover, seen at the cranial pole of the cast (see figs. 12, 13 and 14), corresponding with the three major hepatic veins, which leave the organ at these points. All three are situated in the plane of the fissura dorsalis. These sites can also be visualized extrahepatically in fresh livers after incision of the falciform ligament at the point where this structure merges into the triangular and coronary ligaments (fig. 80). This second hepatic gateway will prove to be as important to hepatic surgery as the porta hepatis[1].

The three rami leaving the organ at this eccentrically located porta have been named vena hepatica dextra, media and sinistra. Next to these major hepatic veins, a number of minor hepatic veins enter directly into the inferior vena cava, becoming visible after the incision of the caval mesentery. These vessels, named by Rex "ventrales kleines Astwerk", coming from the region of the dorsal surface of the liver, will be termed by us *venae hepaticae breves*.

Of the *major hepatic veins* the vena hepatica media appears to leave the organ slightly to the left of the fissura media. For this reason we initially thought that the course of the vessel was also to the left of this fissure (Gans, 1954), but subsequently discovered that this is not so.

After accidental injection of the portal vein under a higher pressure than usual, the main branches of the major hepatic veins were filled with plastic, probably via the sinusoids. We were highly surprised to see that these major branches, which were united at the cranial pole by some plas



Fig 80 Specimen of upper pole of the liver ventral aspect
1 vena cava inferior 2 venula hepatica sinistra cranialis 3 vena hepatica sinistra 4 venula hepatica sinistra interlobaris 5 vena hepatica media 6 vena hepatica dextra 7 venula hepatica dextra cranialis 8 underside of diaphragmatic arch 9 ligamentum coronarium 10 ligamentum falciforme 11 ligamentum hepato-diaphragmaticum

tic that could not escape from the inferior vena cava were lying right in the sagittal fissures This was later confirmed in other casts

From these observations it transpired that the three major vessels of the hepatic vein system, or one of their rami, are located in the fissures described previously, dividing the flow bed of the intrahepatic Glissonian system into a number of lobes *The main branches of the hepatic vein system take an interlobar course*[1] But the main branches of the venae hepaticae are situated not only in the sagittally placed interlobar fissures (*viz* the fissura interlobaris dextra and sinistra and the fissura media), for at the same time the proximal parts of these three

vein trunks lie in the fissura dorsalis Hence in the cranial section of the liver these vessels lie along the lines on which the interlobar fissures intersect the fissura dorsalis

We are therefore able to state definitely that the fissure observed and described by Ruge in one of his fresh livers (1913) (see fig 81) really corresponds with the right interlobar fissure, because he defined it thus 'Die Vena Hepatica verlässt ihn (the right lateral liver lobe of Ruge) am Dorsalende der Substanzbrucke (between the rechter Seiten" and rechter Stammlappen), *sie liegt hier frei zutage*

The hepatic vein, located in the left interlobar fissure, is seldom the vena hepatica sinistra itself, frequently it happens to be a side branch of the left hepatic vein

Rex had already noted that the vena hepatica sinistra drained the left liver lobe and the vena hepatica media the two territories which he indicated as ' Astgefolge der Ramus Ascendens (corresponding with our lobus paramedialis ventralis dexter) and his rechten Astwerk' (corresponding with the lobus paramedialis ventralis sinister) The vena hepatica dextra was said to drain the Verastlungsgebiete der Ramus Ascendens und Ramus Descendens (corresponding with our lobus dexter) and rechtseitiger Abschnitt des Ramus Ascendens which corresponds with the area dorso-lateral to the fissura intermedia this, again, corresponding with part of the dorsal fan area

He pointed out moreover that the proximal part of the left hepatic vein unites with the proximal part of the middle hepatic vein as a short truncus communis before entering the inferior vena cava at the lateral or left ventro lateral wall Though this is the usual occurrence we met instances where the two vessels enter the inferior vena cava side by side

Both Hyrtl (1873) who averred that the right hepatic vein would enter the inferior vena cava at a more cranially located point than the left hepatic vein and Rex stating the opposite are substantially wrong because the two vessels as a rule enter the vena cava at the same level



Fig 81 Liver with externally visible fissures Cranial aspect
1 lobus dexter 2 right interlobar fissure 3 lobus paramedialis dexter 4 vena cava inferior 5 lobus paramedialis sinister 6 left interlobar fissure 7 lobus sinister 8 fissura mediana (after Rüge 1913)

The *left hepatic vein* usually runs straight across the left liver lobe It receives a branch of variable size from the left inter lobar fissure, running ventrally to the pars sagittalis venae portae This branch the *venula hepatica interlobaris sinistra* enters the left hepatic vein at the site where the latter leaves the left liver lobe to take its course towards the inferior vena cava Except for some small branches, practically no blood from the left paramedian lobe is discharged into the left hepatic vein A number of large venous branches enter the lateral wall of the left hepatic vein but it is a striking fact that practically no vessels enter the medial wall of this vessel in the area of the left lobe (fig 82)

The most cranial branch to the left hepatic vein, the *venula hepatica cranialis sinistra,* runs parallel to the cranial left lobar margin usually entering the left hepatic vein within the left liver lobe Occasionally, however, both enter the inferior vena cava as a short truncus and in one instance we even saw them entering the inferior vena cava separately

A branch located more caudally to the left hepatic vein is situated right in the fissura intersegmentalis lobi sinistri it is the *venula hepatica medialis sinistra,* receiving blood from both segments

To the right of the left interlobar fissure the left hepatic vein does not traverse the area of the lobus paramedialis sinistra but follows a course in between the left paramedian and caudate lobe In this region after incision of the coronary liga ments the vein can be dissected out at the cranial surface of the liver (fig 80)

Although the main branch of the *vena hepatica media* runs in the fissura media at the site where this vessel leaves the centro cranial liver pole it is located slightly to the left of this fissura As it enters the inferior vena cava, either united with the proximal part of the left hepatic vein as truncus communis, or is a distinct separate branch, the middle hepatic vein can be dissected out it can, moreover be followed for a short distance in a retrograde direction before its disappearance into the liver

Applying this technique we were able to inject the hepatic venous branches individually especially if the inferior vena cava had been cut too short during the removal of the organ at autopsy This of course was contrary to our normal practice which is to inject all these branches at the same time by way of the inferior vena cava



Fig 82 Specimen of hepatic veins Ventral aspect
1 Vena cava inferior 2 Vena hepatica dextra 3 vena hepatica media 4 vena hepatica sinistra 5 venula hepatica interlobaris sinistra 6 venula hepatica medialis sinistra 7 venula hepatica sinistra cranialis 8 venula hepatica dextra cranialis 9 Hepatic venule from the cranial area of the left paramedian lobe

Blood from both paramedian lobes is discharged by a number of venules into this vein, which is forked at the distal end On rare occasions one may find that the blood of the cranial part of the left paramedian lobe is discharged by way of a separate vein into the left hepatic vein, located to the right of the left interlobar fissure (figs 82 83, 84 and 85)

Nearly all the venulae composing the *vena hepatica dextra*, which is located in the right interlobar fissure, enter this vein at its lateral or ventro lateral surface In a few of our specimens only the blood from the lobus dexter is discharged by way of this vein, in other specimens a variable amount of blood is also carried off by this vein from the area of the dorsal fan of the right paramedian ventral lobe As a rule however the amount of blood carried off from the right paramedian lobe is very small in comparison with the part which is discharged into the middle hepatic vein judged in proportion to the number of vessels The right hepatic vein is the heaviest branch of the hepatic vein system Contrasted with the lobus dexter which is usually the smallest Glissonian lobe a rather heavy branch, the *venula hepatica cranialis dextra*, may, like the corresponding branch to the left, enter the right hepatic vein occasionally it may enter the inferior vena cava slightly cranially to the latter but we very seldom found it to do so in our specimens

We differentiate between two groups of branches from the *venae hepaticae breves* the first the *venae hepaticae caudatae* originating in the caudate lobe and usually as a definite distinct cranial and caudal branch entering high up the ventral or ventro medial vena cava inferior wall The second group consists of a variable number of vessels of considerable size As has been stated these vessels appear after incision of the caval mesentery Two rather heavy branches come from the dorsal region of the right lobe of the liver running superficially immediately below the hepatic capsule (fig 88) Elias & Petty (1952) described these veins in minute detail They called the first which comes in laterally, the *vena hepatica dorso lateralis dextra* naming the other coming dextro caudally which enters the vena cava inferior caudally to the right hepatic vein the *vena hepatica dorsalis* Both the venae hepaticae majores and the venae hepaticae breves fix the inferior vena cava in the liver groove



Fig. 83 Liver, ventral aspect
1 Right stem of portal vein 2 Sagittal segment of left portal vein 3 Right paramedian vein 4 Saccus 5 Left caudal paramedian vein 6 Paraumbilical vein 7 Caudal vein of left lobe 8 Cranial vein of left lobe 9 Cranial vein of right lobe 10 Caudal vein of right lobe 11 Right hepatic vein 12 Right cranial hepatic venule 13 Medial hepatic vein 14 Left interlobar hepatic venule 15 Left cranial hepatic venule 16 Left hepatic vein

Whereas, normally, shunts are not detectable in a portal vein specimen between the different areas of ramification, we frequently found anastomoses between the ramifications of the hepatic veins as did also Elias & Petty (1952)

Having considered the normal topography of the hepatic



Fig 84 Heavily tinted branches portal vein Faintly tinted branches hepatic vein Ventral aspect
→ ← Portal vein branch with corresponding artery

veins let us return to the embryonic development of these veins Contrary to Mall (1906) we imagine that when the two primary lobules meet the umbilical veins the proximal parts of these veins which are also incorporated in the expanding liver tissue retain their interlobular position unlike the distal part Hence the vein on the right becomes the vena hepatica dextra and that on the left the vena hepatica sinistra



Fig 83 Ventral aspect Heavily tinted branches portal vein system Faintly tinted branches hepatic vein system
→ Left interlobar hepatic venule

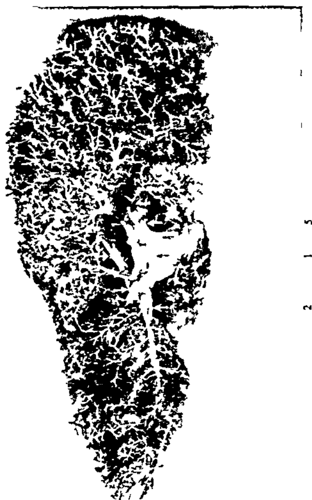


Fig 86 Portal vein hepatic vein specimen cranial aspect

1 vena cava inferior 2 vena hepatica sinistra 3 vena hepatica media 4 branches entering the medial hepatic vein 5 Right hepatic vein



Fig 8, Portal vein hepatic vein specimen ventro-cranial aspect Maximum filling of the right hepatic vein sharply defining its area of ramification bounded by line A A



Fig 88 *Portal vein hepatic vein specimen with marked reduction of the left hepatic lobe'* Dorsal a.pect 1 Inferior vena cava 2 vena hepatica dorso-lateralis dextra 3 vena hepatica dorsalis 4 Left hepatic vein 5 Portal vein at the hilum



Fig 84 Grooved liver after injection of all four structures Ventral aspect Faintly tinted branches hepatic veins heavily tinted branches portal veins Complete interdigitation of the structures of both systems
1 Vena cava inferior 2 3 en 4 Grooves 5 Umbilical incisure

After obliteration of the left proximal vitelline vein, the blood of both paramedian lobes which initially had their own efferent veins, is now discharged by way of the right proximal vitelline vein which shifts to the mid line and thus assumes an interlobular position. We agree with Mall when he says: "Each interlobar vein at this stage is to form a main trunk in the adult".

In our opinion the relationship between the embryonic development of the venous system and the lobar division of the liver calls for further investigation, but the subject is beyond the scope of the present study.

Chapter VI

SURVEY OF THE SUBDIVISION OF THE LIVER

In this final chapter on the anatomy of the liver, we shall endeavour to co-ordinate the details relating to the lobation of the liver set forth in the foregoing with the intention of portraying the organ in a manner that will integrate the divisions according to the Glissonian and venа hepatica systems into a morphological and functional unity. It will be plain from what follows that we are now entering upon a highly controversial subject.

At the outset we based the internal subdivision of the human liver upon that familiar as the Glissonian system—a subdivision which, up to a point, was found to correspond to the external division initially submitted by Von Haller and later elaborated by Ruge and De Burlet *inter alia*.

Guided by the striking relationship between the two systems, we eventually mapped out an internal subdivision of the organ on the lines of the ramifications of those systems. This subdivision turns out to coincide partly with a division laid down in the past by others.

We make no claim to having uttered the last word on this complicated matter. The solutions suggested were conceived in a *surgical* climate, the predominant aim in the division being to resect such areas as comprise the divisional regions of the *afferent* as well as of the corresponding *efferent* structures. For all that—and we wish to make a point of stressing this before

hand—we were not able to adhere consistently to this division for all the surgical procedures dealt with in this work

Our point of departure in this division of the organ subject to the two systems was a comparison of the spatial inter relationship between the two intrahepatic systems in the lobated liver of the dog, which was initially injected to serve as a guide in our experimental surgery (see Chapter VIII), and the unlobated human liver

Somewhat closer inspection of a dog s liver will reveal certain differences as compared with the human liver First of all there are a number of visible fissures radiating from the inferior margin at some depth towards the centre of the organ, giving the liver a lobated appearance Secondly, it will be seen that the peripheral ventro-caudal parts of the liver are less voluminous than in the unified human liver they consist of large flat parts in contradistinction to the centre of the organ which is far more bulky Finally, the distance between the two hepatic gateways *i e*, between the porta hepatis and the point at which the hepatic veins leave the liver is relatively shorter

There are also characteristic internal differences Whereas the portae were seen to ramify in the human liver in all directions except dorsally, the branching of both the vena portae and of the vena hepatica is digitiform in the dog s liver The branches of the two systems radiate like the fingers of a hand into the various lobes

In the flat thin, peripheral areas of the liver the structures of both systems run parallel and in close proximity to each other Towards the centre the two systems diverge *viz*, the bile ducts with the corresponding structures of the Glissonian system towards the hilum and the hepatic veins towards the central cranial liver pole Owing to the relatively short distance between these two gateways in the dog the distance between the different structures of the two systems is usually small yet large enough to permit the two systems to interdigitate in the bulkier central part of the liver (figs 90 and 91)

In the periphery of the liver, however, the various areas of *ramification are identical in the two systems*, which accounts for the sharp demarcation of those areas by fissures and the lobated appearance thus imparted to the organ

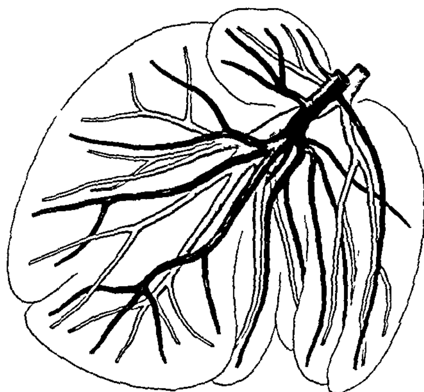


Fig 90 Liver of a dog dorsal aspect Light branches of the hepatic vein Dark branches of the portal vein

Without entering into the *individual structures* of the two systems in the dog s liver we may generalize by saying that a characteristic difference exists in *the relationship between* the two systems as compared with the human liver

As we have seen, although there are indications of a lobation on the visceral surface of the human liver, this characteristic feature is much less pronounced than in a dog's liver. In the human organ the distance between the two gateways is relatively larger than in the dog and, in fact, the majority of mammals with lobated livers.

Another distinctive feature of the human liver is the caudate lobe between the two gateways as a tissue bar, lacking in the dog's liver, in which this lobe takes the form of two separate lobes, turned far more laterally behind the side lobes and having no contact in the median line.

In the human liver, the branches rising from a crosswise placed vena portae situated in the sulcus transversus spread in all directions except dorsally. Although, at first sight, these ramifications seem to be rather chaotic, a certain amount of symmetry does appear to prevail in the origin and course of the portal main branches, as Rapp (1953) and Couinaud (1954) have pointed out. The division of the various main branches of the vena hepatica system of the human liver is digitiform in the same way as in the dog's organ.

Briefly summarising our findings for the human liver, we may say that the flow beds of both the Glissonian and vena hepatica system can be subdivided into various areas. These areas are far more sharply defined in the Glissonian than in the hepatic vein system.

The main branches of the hepatic vein system are located in the interlobar fissures, according to which the different Glissonian areas are demarcated and the venules entering these veins interdigitate with the portal vein rami. There is practically no parallel course in the periphery of our specimens, such in contrast to Glisson's illustrations (see fig 4, p 10). On account of the greater distance between the two hepatic gateways, the structures of both systems disperse almost immediately. Yet a correlation exists between the areas of ramification of either system. As noted previously, the area

drained by the left hepatic vein is restricted to that receiving blood by way of the portal vein bed, corresponding with the lobus sinister, while the area drained by the right hepatic vein consists almost entirely of the lobus dexter area, moreover, the middle hepatic vein drains nearly all the blood supplied via the ramifications of the portal veins of both paramedian ventral

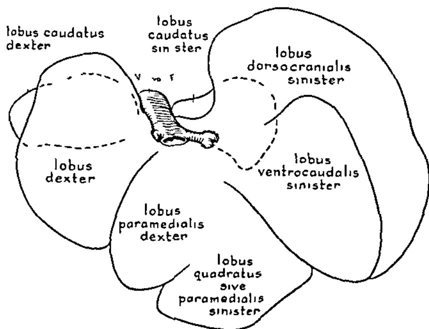


Fig 91 Division of the dog's liver into lobes ventral aspect

lobes The caudate lobe, as was seen, has its own routes of drainage, immediately into the inferior vena cava

Up to the present, the liver has been divided rather arbitrarily it might seem according to the Glissonian system Is this division really an arbitrary one? After all, we have seen that this division corresponds to a certain extent with the external subdivision after Von Haller and Ruge Gersbein & Elias

(1954) who were obviously aware of this problem, solved it in this way One takes the division of the portal vein branches as guides, the lobes are named after the portal branches which supply them, since among mammals the portal tree is the most constant gross anatomical system'

Judging by our own observations we believe the same can be said of the division of the hepatic veins, in the intrahepatic course of which very few variations have come to light

In the Glissonian system of division we distinguish two halves of the liver each again subdivided into two lobes a division which as has been seen, agrees with that introduced by Flowers Cantlie etc For the division according to the vena hepatica system we can now divide the liver into three ventral lobes, a right, left and middle lobe, and this agrees with the division introduced by Ruge De Burlet and others Thus we are here faced with a long standing controversy This controversy, pointed out by F Meyer (1911), was not yet understood as such because his investigation was based solely upon a study of the external aspect of the different liver types

In between the multiple lobated liver as in the dog and the unlobated organ there exists a group of livers *e g* that of the pig the hepatic vein ramifications of which are not purely intermedial to the counterparts of the Glissonian system as existing in the unlobated type neither do they run parallel, as in the periphery of the dog's liver It is mainly this group of livers which is probably responsible for the existing controversy, because these livers consist of three distinct lobes, though an indication of the fissura media is seldom lacking The course of the hepatic veins therefore also affects the external appearance of the organ which as such may serve as an argument to those who take its intrahepatic ramifications as the basis of the subdivision of the organ

Histologists have been preoccupied with this controversy for some considerable time but a satisfactory solution has not yet been forthcoming

Kiernan (1833) described the lobule as a *morphological unit*, centred around the central vein (hepatic vein branch). Sabourin (1864) argued that for the liver, as a gland with external secretion, the morphological division consequently ought to be abandoned and replaced by a *functional unit*, centred around the bile duct. Bichat (1801) must have known this argument, for he remarked that nature never would have created an organ of this size for the sole purpose of producing a secretion of which the quantity stands far behind that of urine. Since Claude Bernard (1877) pointed out that the organ derives its main importance from its endocrine function, the division proposed by Sabourin has been completely discarded.

Again and again voices were raised against Kiernan's concept demanding a revision, as by Mall (1906), who introduced the 'portal unit" and recently by Rappaport *et al.* (1954) who introduced the 'hepatic artery unit', both approaching the concept of a functional unit as originally proposed by Sabourin.

Similary, one is able to divide the gross structures of the organ in three ways: firstly a division based upon the segmental distribution of the "functional unit structures" (structures of the Glissonian system), secondly, the division of the organ into areas of ramification of the "morphological unit structures" (hepatic veins) and thirdly a division based upon the distribution of both functional and morphological unit structures (both intrahepatic systems).

For our purpose, *i.e.*, the resection of parts of the liver, we should, if reasonably possible, adopt the third alternative subdivision, seeing that a liver lobe, according to this system, not only has its own Glissonian pedicle at the porta hepatis but at the same time its own vena hepatica pedicle at the upper pole of the organ. That lobe is therefore not only a morphological or functional unit of the liver, but a *surgical* one as well.

This division can be represented schematically as follows

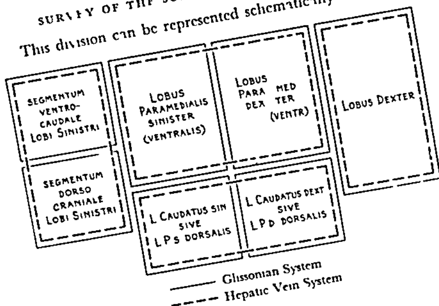


Fig 92

In this divisional pattern the organ as a whole is no longer a paired one Resection of one half of the organ is therefore called hemihepatectomy

Three lobes can be distinguished for this type of subdivision which also corresponds to that for the arborization of the hepatic vein system into a right, left and middle lobe the latter being subdivided into a ventral and a dorsal lobe In the surgical section we shall consequently discuss the resection of the lobus dexter medius and sinister, the so called right, middle and left hepato lobectomy also respecting the lobus dexter in conjunction with the lobus medius, the resection of the pars dextra hepatis

This divisional pattern corresponds neither with Von Haller s nor with that proposed by Ruge and De Burlet, though it approaches the pattern proposed by the last two authors The difference resides in the demarcation of the middle lobe for Ruge divided the middle lobe into three Stammlappen

for the Glissonian system, namely the lobus dextro vesicalis (our lobus paramedialis dexter), a lobus praeportalis (our lobus paramedialis sinister) and a lobus centralis sinister (our segmentum ventro caudale lobi sinistri) The last one definitely belongs to the left liver lobe for all three types of division However, the fact that these investigators at that time approximated the true facts solely on the basis of a comparative anatomical study of the external aspect of the organ, only increases our admiration for their work

Chapter VII

INDICATIONS FOR HEPATIC SURGERY

Before proceeding to discuss the surgical implications of the foregoing anatomical findings, we would do well to consider whether or not there exists any need for surgical techniques of the kind

After studying the literature and the indications valid for classical hepatic surgery we find that the diseases of the liver which may call for surgical intervention are so numerous that it will be necessary to set a limit even to the establishment of indications For the time being, therefore we shall consider as indicated for the new form of hepatic surgery only those solitary pathological conditions which are apparently inaccessible to any other type of therapy, leading, if untreated to the death of the patient

There are to our mind, two reasons which make this limitation obligatory firstly because this new form of hepatic surgery is still in its infancy and, secondly because this surgical therapy is a form of radical surgery comparable to a radical mastectomy an amputation and a pulmonary resection which like these procedures should be resorted to only under dire necessity

In a study of this kind, personal preference must inevitably colour a selection from the list of pathological conditions which will therefore no doubt incur criticism from some readers as being incomplete It is nevertheless our avowed inten

tion to dwell only on the repercussions which this new form of surgery may have on the treatment of *tumours* and *deep lacerations* of the liver, i e, conditions which demand an operation as the one and only means, more often than not, of saving the patient's life Until more experience has been gained in the new type of surgical treatment we cannot tell whether it is applicable to other pathological conditions as well

A NEOPLASMS OF THE LIVER

It is safe to say that, as a rule, the smaller primary hepatic tumours are not diagnosed, being discovered only at autopsy It is the larger tumours which cause symptoms and only a minority of these are accessible to the knife, depending on localisation, type of tumour and the stage reached at the time of the diagnosis

The benign tumours qualifying for surgical exploration and, possibly, resection, are solitary tumours manifested as an upper abdominal mass, usually accompanied by mechanical disturbances The appropriate malignant tumours for this treatment are massive, solitary tumours, revealing themselves in the same way as the benign growths, with or without the vague signs and symptoms often associated with malignant tumours, such as prostration, anorexia, loss of weight, weakness, gastric disturbances constipation, abdominal pressure dyspnoea, occasional pain, etc

Because of their rather infrequent occurrence in the Western Hemisphere, solitary hepatic tumours are usually mistaken for other conditions The differential diagnosis is in general incomplete, due to the fact that little is known of these neoplasms and operation is therefore often postponed until the condition has become inoperable Moreover, owing to the unsatisfactory method of hepatic haemostasis and the problems arising from cholerrhagia, only few surgeons attempt eradication of a primary or secondary tumour, even

though this procedure may prolong or even save the patient's life

However, the new type of surgery, which enables the surgeon to resect liver portions along relatively avascular and aductal planes (the interlobar fissures, previously described), evades these dangers and will consequently stimulate a renewed interest in hepatic pathology We shall therefore briefly survey some pathological features of those hepatic tumours which are amenable to surgical therapy

The following classification of primary hepatic tumours is followed (after Warvi, 1945)

1) Hepatomas
   a) liver cell adenomas
   b) liver cell carcinomas with or without cirrhosis
2) Cholangiomas
   a) adenomas of intrahepatic bile ducts solid or cystic
   b) carcinoma cholangio cellulare
3) Cholangio-hepatomas of both liver cell and duct elements
4) Primary tumours of the liver without specific hepatic elements (vascular, fibrous, adrenal rests etc)

Hepato cellular adenoma, which is indistinguishable macroscopically in its multiple form from nodular hyperplasia in cirrhosis of the liver usually occurs *solitarily* These solitary adenomata are prone to assume enormous dimensions, either because of their gradual enlargement or because of their very rapid expansion in a comparatively short period, a period liable to vary from a few months to many years

Hepato cellular adenomata are always encapsulated, solitary tumours marked off in colour from the surrounding liver tissue They are usually light brown or a pale grey on account of the high fat and glycogen content of the cells sometimes these tumours are tinted by bile Coming upon them accidentally during laparotomy the surgeon might easily mistake them for metastases in the liver

On examining this tumour the histologist will generally find that although the cells are somewhat larger and coarser than

the liver cell, they nevertheless strongly resemble it and that the adenoma cells likewise present a trabecular arrangement

As Warvi observed, adenomata are isolated both anatomically (by a capsule) and physiologically from the normal liver tissue on account of the absence of the portal triads in the tumour, hence the bile, which is sometimes produced by the cells of the tumour, cannot be drained

These, then, are the characteristic features distinguishing this growth from the lump seen in nodular hyperplasia, which is not encapsulated (Simmonds, 1884) and in which the bile ducts do communicate with the rest of the organ

Adenomata are liable to become so large that they give the patient mechanical discomfort It is of supreme importance to ascertain the rapidity of growth in view of possible malignant changes For, with reference to this hepato cellular type of tumour, Deelman, Kaufmann and many others have stated that there is no essential distinction between the comparatively benign (adenoma) and the atypical malignant forms (carcinoma)

In the benign hepato cellular type of tumour, the solitary adenoma, the veins are not invaded but the benign character is due chiefly to encapsulation and transitional forms to adeno-carcinoma occur in which there is invasion of veins and multiplication of tumours (Ewing) It is not surprising therefore to learn of cases in which the original diagnosis of adenoma had to be revised after its surgical removal upon subsequent metastazation (Von Bergmann, 1887, Wendel, 1911, Varadi 1937, etc)

If the encapsulated tumour is detected during exploration, a test excision can serve no useful purpose, on the contrary, it may be injurious to the patient, because in the case of adenoma only multiple sections are capable of ruling out malignant changes Accordingly, resection without preliminary biopsy is then indicated

We agree with Seneque and Auroussean (1952) that, even

if the tumour is well encapsulated, it should be resected with a generous margin and *not enucleated*, for, in the event of malignant changes, such as invasion of the vessels by the cells of the tumour, manipulation is only too likely to provoke an embolism of the tumour cell

Though some may disagree, we share Warvi s view that The mistaken identification of adenoma as carcinoma appears less serious in view of the mild surgical risk of exploration, which is justified in view of the rapid fatal prognosis for untreated carcinoma

There are two distinct types of *hepato cellular carcinoma, viz*, with and without cirrhosis of the liver Macroscopically we differentiate between three forms solid carcinoma, multiple growths without a distinct primary tumour and the diffusely growing carcinoma

The great majority of the hepato cellular types of malignant tumour develop in cirrhosis hepatis, a disease contraindicating resection It is a tumour of very frequent incidence in tropical and subtropical regions populated by backward peoples Bonne (1935) found that all his Javanese cases of hepatic tumours were hepato cellular cancers in cirrhotic livers Berman s statement (1950) that cirrhosis of the liver is always present is only related to his material In collective statistics of 893 cases of primary carcinoma of the liver the incidence of cirrhosis was 67 2% (Berman)

Of the tumours occurring in livers free from cirrhosis, which, again can be subdivided into the multiple nodular type and the solitary type it is the latter which stands the best chance of cure by surgery, despite its rapid growth because the rest of the liver is usually normal

This type of tumour, which is amenable to surgical treatment, is known under the names of 'adenoma malignum (Ribbert, 1909, Cathala 1923) cancer massif (Hanot & Gilbert 1888) 'primary massive encapsulated carcinoma (Warvi 1945), or carcinoma in the form of a single

massive growth" (Nicholls *et al*, l c Warvi) *Its exact incidence is unknown* It may grow out at any time during foetal (*Noegenrath's case*, 1854) and postnatal life

According to Warvi, this type of tumour frequently appears to arise from an adenoma, "and the lesion exhibits all degrees of change from benign adenoma with slight cancerous transformation to highly anaplastic carcinoma

These gray, yellow or bile stained tumours, which are encapsulated and/or project over the liver surface, may reach enormous *dimensions They may be bossed in appearance*, while the hepatic capsule overlying the tumour is generally thickened, and, as in the case illustrated in fig 93, firm adhesions may be present between the capsule and the adjacent organs or diaphragm In cross section the tumour may be found to be confined to one lobe (fig 94), while its colour varies from white to gray, yellow, or brownish red, the consistency also varies greatly, depending upon the extent of the degenerative changes In the tumour represented in fig 93 the cross section was lobulated

Histologically, the tumour cells may present various stages of dedifferentiation (*fig* 95) *In the more benign forms, these cells* usually resemble liver cells more or less, containing a basophile protoplasm They are arranged in trabecular *formations In* the more malignant forms, the cells are arranged in alveolar like formations and show little or hardly any resemblance to liver cells Even the highly malignant tumours may produce bile, however

The tumour may increase considerably in size in a relatively short period of time In Eggel's series of 14 cases (1901) exhibiting an hepato cellular carcinoma of the massive type the duration of symptoms ranged from 2 weeks to 6 months The average age *incidence* of this type of tumour is the 5th to 6th decade of life even though some cancers of infancy and early childhood *of Dansie's (1922) and Steiner's (1938)* collective reports belong to this group (fig 96)

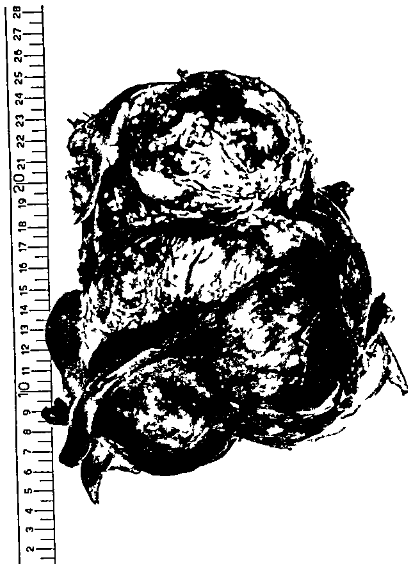


Fig 93 Solid solitary primary carcinoma of left half of liver removed surgically (left hemi hepatectomy) Weight of the tumour 1950 grams size 19 × 14 × 12½ cm (Operation by Pernet & Gans July 1954)



Fig 14 Same tumour as in fig 93 in cross section

Many authors have noted that males are predominantly affected

This group of solitary tumours is usually of unicentric origin and is therefore suitable for surgical treatment Several features

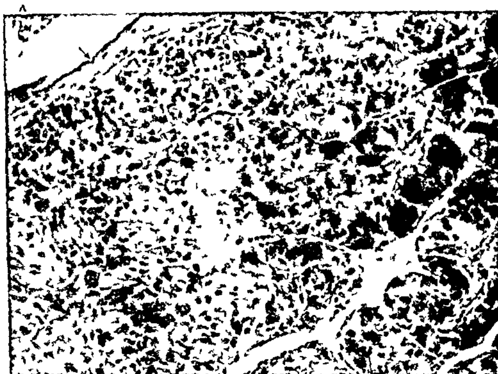


Fig 95 Microscopist's report of the tumour in fig 94 hepato-cellular carcinoma a capsule of the tumour

of this malignant type of tumour are still incompletely understood to day The tendency of hepato cellular cancers to invade the venous channels, in contrast to the preference of cholangio-cellular cancers for the lymph channels, is one of the problems (Herben, 1948, Seneque & Aurousseau 1950 etc), another is the fact that the tumour is usually situated in the right liver lobe

Generally speaking *extrahepatic* dissemination takes place late in the course of the disease *Intrahepatic* dissemination is quite common Numerous small nodules, apparently metastatic deposits, may be present in the adjacent liver tissue even early in the course of the disease

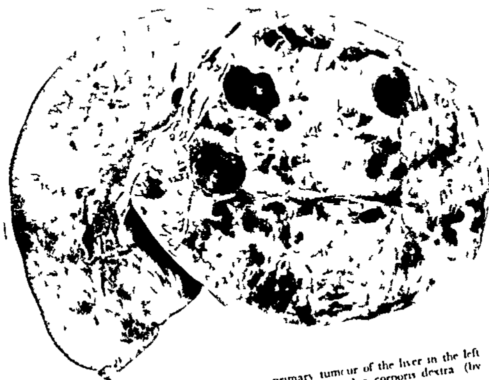


Fig 96 Encapsulated massive solitary primary tumour of the liver in the left hepatic lobe Female 10 months with hemi hypertrophia corporis dextra (by courtesy of dr J C Hette)

X ray treatment may give brief symptomatic relief in hepatic malignancy as recently shown by Philipps *et al* (1954), but no lasting cure

It will be obvious from this brief survey that these solitary hepato cellular tumours offer an absolute indication for resection

Confidence has for long been placed in the surgical treatment of the disease, as is clear from many reports in the literature, but, owing to the risk attached to the surgical procedure itself, the high hopes entertained have in the ultimate seldom been realised, notwithstanding some spectacular results such as those obtained by Wendel (1911), Brunschwig (1947, 1953) etc

There are some other lesions which may occur in the liver at any age of life They may either give rise to mechanical distress on account of their size, or be discovered incidentally during, let us say, laparotomy, when they may be mistaken for primary or metastatic carcinoma of the liver Such tumours include the second group distinguished by Warvi, *viz* the cholangiomas

We need only touch briefly on the *cholangiomas* which are congenital tumours of the bile duct epithelium, as they are far less frequent than the hepatomas Seldom solid, they are usually cystic through the accumulation of mucus, which causes them to grow to an immense size These tumours, which never produce bile usually cause trouble at an earlier age than do adenomas They may be benign or primarily malignant but degeneration to malignancy is also known though less frequently than in the case of hepato cellular adenoma degeneracy of a cystic cholangioma has for all that, been reported (Willis 1943) Cholangio cellular cancers are far more rare than hepato cellular carcinoma, they represent about 1/5 of all the primary malignant tumours of the liver

Microscopically the tumour is characterised by its glandular structure and an abundant dense, relatively avascular stroma

Its clinical prognosis is even more rapid than that of hepato cellular carcinoma

The following tumours *viz* those primary tumours of the liver which Warvi classifies under groups 4 and 5 have only one common feature, that of probably originating in a congenital malformation of tissue

The nature of the embryonic liver tumours or hepato-blastomas (Willis) is determined by the stage of development during foetal life in which the congenital malformation arose and the kind of tissue components influencing the growth

If there are tissue components completely foreign to the organ (group 5 of Warvi) these heterotropic tissues may be arranged in organoid structures choristomy (Albrecht 1904) Choristomas are growths which may derive from these

Heterotropic tissues without an organoid structure such as epidermoid epithelium bone cartilage striated muscle are called teratomas

These types of malformation probably arise at an earlier stage of development than those described in the following paragraphs

If heterotropic tissue is absent homologous tissue components (group 4 of Warvi) may become isolated in such a way that anatomically or physiologically they are no longer incorporated in the normal structure of the organ If we are dealing with an abnormal mixture of several homologous tissue components this condition is usually indicated as hamarty (Albrecht 1904) when they develop we call them hamartomas This group comprises the cholangio-hepatomas

Malformations caused by one homologous tissue component may be divided—though occasionally no sharp distinction can be made—into areas solely composed of one of the epithelial structures which are liable to develop into hepatoma and cholangioma and those showing a preponderance of one of the mesenchymal derivatives which are liable to develop into haemangioma and lymphangioma

Naturally enough the terminology suffers a good deal from confusion and it was for this reason that we thought it would be useful to go briefly through Albrecht's formulation

Some tumours removed at operation, such as those reported by Ladd & Gross (1941), Benson & Penberty (1942), Lee (1942), Patton (1948), etc , all in *infants* and *young children* were described as hamartomas, but were essentially teratomas, comprising, as they did, bone, cartilage and the like These tumours as a group, are seldom potentially malignant and the number of reported cases of *terato carcinomas* (all in young children), namely by Skifosovsk (1896), Philipp (1908), Hippel (1910) Yamagiva (1911), Castle (1914), Sheehan (1930), McRae (1935) and Roth (1938), are few

The case reported by Lee (1942) of a tumour weighing 4½ pounds removed from a baby of 13 months, testifies to the

fact that benign teratomas are likewise liable to assume enormous proportions These tumours may however also be multiple and have even been known to be associated with congenital abnormalities elsewhere (Schmelling 1934)

The *hamartomatous cholangio hepatomas* of which recently a few cases were reported by Kay & Talbert (1950) are in general roughly nodular encapsulated tumours with a light reddish tan colour Most cases occur in infants and children These tumours may occasionally assume considerable dimensions with diameters up to 20 cm and weights up to 2 kg

Histologically these cholangio hepatomas are composed of rounded masses of liver cells arranged in cords and bile ducts Both anatomically and physiologically the tumour is isolated from the surrounding normal hepatic tissue These masses lack the orderly structure of liver lobules and do not have a central vein They are surrounded by areas of fibrous tissue containing many bile ducts and small blood vessels (Gerding *et al* 1951)

Malignant cholangio hepatomas are usually associated with cirrhosis in which case the tumour is not amenable to surgical treatment

Let us in conclusion consider the cavernous *haemangioma*, a benign tumour which may on very rare occasions become malignant (Ewing 1928)

The incidence of haemangiomas becoming large enough to be detectable is small Shumacker (1942) collected 66 reports of benign hepatic haemangiomas of which 56 cases were operated upon since then this number has increased In Shumacker's series, recently extended by Riddler & Madding (1949) the livers were enlarged and the normal tissues were extensively replaced by masses of growth with average dimensions of 12 × 12 cm and an average weight of 900 grams

Macroscopically the growths appeared as knobby cavernous cysts bulging through the surface of the organ they were blue black in colour Usually these tumours are sharply mark

ed off from the parenchyma by a capsule, or project from the surface as a pedunculated mass. The diffuse form is rarer. These tumours are often observed in the left liver lobe, occasionally in association with angiomas in other organs. The smaller ones are accidental findings at autopsy, they may even disappear spontaneously from thrombosis or inflammation, only leaving some scars. When these tumours develop, they may increase slowly in size with the age of the subjects (Ewing, 1928). If they become very large, they are prone to burst, causing intraperitoneal haemorrhage (Hendrick, 1948).

The few cases described as malignant haemangio-endotheliomas ran an extremely rapid fatal course (Hasting James, 1949). The question is still open for discussion whether the occurrence of these tumours elsewhere should be regarded as metastases, or only as a manifestation of the multicentric origin of the tumours (Willis, 1940).

Rare as primary tumours of the liver are, solitary hepatic tumours amenable to surgical therapy are more infrequent still. The action called for in the case of a patient suffering from a solitary tumour of the liver must depend to some extent upon the circumstances. Both biopsy and enucleation of the tumour are contra-indicated in the event of rapid growth in a comparatively short period. The future may possibly bring a more sharply defined set of indications but, for the time being *wide resection is advisable in every patient in a good general condition who exhibits a rapidly growing hepatic tumour*.

Metastatic tumours of the liver

Virchow's rule (1888) to the effect "dass fast alle diejenigen Organe welche eine Neigung zu protopathischer Geschwulstbildung zeigen, eine sehr geringe Neigung zu metastatischer darbieten und umgekehrt" ("that almost all organs susceptible to protopathological growths exhibit very little tendency to harbour metastases, and vice versa") is certainly not without

relevance to tumour pathology of the liver As will have appeared from the preceding brief review, primary liver tumours are rare in our part of the world

Secondary infestation of the liver, however, is a quite common occurrence, either by direct extension of the tumour growth as in cancer of the gall bladder, colon and stomach, or by way of the blood channels

In Walther s series (1948) of 20660 autopsies the incidence of primary cancer of the liver was 0 26%, that of secondary tumours 4 7%

The incidence of liver metastases in the various types of cancers as found at autopsy (Philipps *et al*, 1954) is for cancer of the breast 50%, for cancer of the bronchus 40%, for cancer of the stomach 40% for cancer of the colon 45% and for cancer of the oesophagus 25%

In a given case of cancer of the liver in a man, the probabilities are 20% that it is from the stomach, 20% from the intestine, 14% from the genito urinary tract and 14% from the other digestive organs In a female the probabilities are 20% from the breast 18% from the intestines 13% from other digestive organs 16% from the uterus, 12% from the stomach and 7% from the genito urinary tract (Setterlee l c Anderson)

These figures show that the majority of metastases in the liver derive from those organs which drain their blood into the liver via the portal vein

On going through 1200 unselected autopsy reports we found that the diagnosis of malignant tumour was made 165 times 64 times of which pertained to an organ draining its blood into the liver by way of the portal vein Fifty of these 64 cases showed distinct metastases in the liver (78%)

Schroeder van der Kolk (1853) was the first to point out that the liver is usually the first organ involved by tumours of the gastro intestinal tract pancreas, and gall bladder by invasion of tumour growth into the peripheral branches of the

portal vein This idea has recently been re introduced into oncology as "portal vein type of metastazation" by Walther (1948) and Wieberdink (1950)

Serege, and later also Wassink (1915), Copher & Dick (1928) and Mermans (1946), tried to explain the localization of the pathological process in the liver

Serege, who propounded the theory of "le double courant sanguin à l'intérieur de la veine porte" (the double blood stream inside the portal vein), noted that les ondes sanguines de la grande mésentérique et de la splénique, obéissent chaque à son propre courant Elles se juxtaposent et cheminent côte à côte, parallèlement à la paroi de la veine, sans se confondre séparées par une barrière liquide virtuelle qui s'oppose au mélange des deux sangs (the waves of blood in the superior mesenteric and splenic veins follow each their own course They are juxtaposed and travel side by side, parallel to the wall of the vein, without mingling, separated by a liquid barrier as it were, which prevents the two bloods from mixing)

Organs discharging their blood into the superior mesenteric vein would metastasize to the right those by way of the splenic and inferior mesenteric veins to the left half of the liver because of the stream lined effect of the portal vein blood Though these observations would appear to be probably correct in the main, they do not take into account the variations occurring at the site of entrance of the tributaries composing the portal vein As was seen previously (page 65), both Douglass *et al* (1950) and Gilfillan (1950) proved by their dissections that the number of variations in the composition of the portal vein are so many, that one cannot predict with absolute certainty the site of all secondary deposits in the liver

Therefore those (Lefevre, ... ers) who
left hepato lobectomy, for ex... ine
every patient with carcinoma ... h, ...
far Moreover Lortat-Jacob ... 52)

resection of the pars dextra hepatis for gastric metastazation on the right instead of, as one would expect with Serege and others, on the left half of the liver

Hence as has been stated previously (see page 66), *the exact localisation of metastases in the liver can seldom be confidently predicted*

Late metastases of carcinoma, following removal of the primary tumour, may occur without local recurrence, as is demonstrated by the case described by Solomon & Kreps (1950) of a patient who manifested a metastasis in the liver no less than 26 years after undergoing sigmoidectomy for adeno carcinoma!

Moreover spontaneous disappearance of macroscopic secondary growth has been reported for the liver after the removal of the primary tumour, as it has for the lungs (Fletcher, 1948) This ought to be considered as a rare occurrence

Resection of solitary metastases in the liver together with the primary tumour has been advocated (Wangensteen 1945 Brunschwig 1947 1953 etc)

In many instances however, it may be exceedingly difficult to determine with absolute certainty, only by palpating the organ (especially its more bulky parts) whether one is dealing with an isolated metastasis as appears for example from Golligher s series of cases Of his 31 patients who had died a few days after radical operations on the rectum and whose liver did not appear to be involved during the operation five proved to have deep metastases in the liver (l c Willis) An hepatogram taken during the operation may aid in giving a conclusive answer (See Appendix II)

It is a fact that isolated metastases may occur in the liver as a solitary metastasis or occasionally as a few nodules located in one and the same area The number of these cases may indeed be greater than is generally supposed In 10 patients who came to autopsy with cancer of the pancreas one showed an isolated metastasis without further macroscopic evidence of dissemination while in 21 cases of cancer of the stomach 2

showed isolated hepatic metastases, while 4 other cases showed a local regional lymph node involvement next to these

Brunschwig's statement (1948) that direct extension of cancer of the stomach or transverse colon *is impossible on account of the fact that Glisson's capsule "is an effective barrier to infiltration of malignant cells, and in most instances actual invasion of the growth through the capsule into the liver has not occurred"* applies only to the protective role of the capsule against carcinoma of the stomach and the colon

The Glissonian capsule of the fossa cystica, located in between the gall bladder and liver, however, certainly is not such an effective barrier as witness 14 cases in our series exhibiting carcinoma of the gall bladder Four of these patients showed only macroscopic involvement of the liver without any further evidence of metastization, three others exhibited local liver involvement with extension of the tumour into the regional lymph nodes

Considering that Lam (1940) estimated the mortality from carcinoma of the gall bladder in the United States at 6500 cases per annum, the urgency of extending the scope of surgery to this disease will be realised We have therefore long been seeking a method by which the early cases at least of carcinoma of the gall bladder could be resected Before describing this method, we shall discuss some features of the tumour itself

The incidence of cancer of the gall bladder as found on the total number of autopsy cases varies between 0 34% (Jones 1950) and 0 81% (Von Bareneszy *et al*, 1924)

The incidence of gall bladder carcinoma on the number of autopsy cases in which carcinoma was the cause of death varies between 2 1% (Walther, 1948), 2 8% (Illingworth 1935) 3 8% (Schornagel & Straub 1954) 4 5% (Lam 1940) and 6% (Graham 1931)

In Hyden's series (1950) this disease was the sixth in the order of frequency among the fatal cases caused by carcino

ma following immediately upon carcinoma of the breast

The incidence of this disease on the number of operations on the biliary tract varies between 0 87% (Vadheim *et al* 1944) and 3% (Jankelson, 1937)

Carcinoma of the gall bladder affects women far more frequently than men Walther found the incidence in females 75%, Kaufmann 87% and Wieberdink 89%

Though reports have been published on exceptionally young patients *e g* Biering s report (1946) on a 13 year old girl the average age for carcinoma of the gall bladder was 65 years (Walther s series)

The probable relationship between carcinoma of the gall bladder and cholelithiasis was pointed out for the first time by Frerichs (1861) The incidence of gall stones in gall bladder carcinoma ranges from 65% (Walther) to 94% (Finsterer, 1932) Stewart (1931) found 30 cases with gallstones in his series of 43 gall bladder cancer patients (±70%), as compared with 16 4% in the control series The incidence of cancer of the biliary tract in the cholelithiasis cases was 3 8% and 0 4% in the controls The difference (3 4 ±0 59%) is highly significant

Crump (1931) found convincing evidence of the relationship between stones in the biliary tract and advancing age, he even observed an incidence of 70% for the age groups past the seventh decade

Walters and Snell (1940) believe that the incidence of carcinoma of the gall bladder has decreased since the introduction of cholecystectomy for cholecystitis and cholelithiasis, especially after the perfection of the radiological methods of diagnosis of these diseases

It is therefore an accepted fact that the most efficient prophylactic measure against the development of carcinoma of the gall bladder is cholecystectomy in manifest or silent cholelithiasis Controversy rages however between those who advocate cholecystectomy as a routine procedure and those

who believe that the mortality of cholecystectomy is as high as that of cancer on the basis of stones The latter figure varies between 2 and 5%, the former between 0 6 and 1 5% (Sainburg & Garlock, 1948, Graham, 1931) This is still a considerable difference in favour of those who defend routine surgery as a prophylactic method

Yet, in view of the fact that in Stewart s series, for example, 16 4% of all who came to autopsy suffered from gall stones a general effort to reduce incidence of gall bladder carcinoma would imply prophylactic cholecystectomy in one sixth of the population Because carcinoma of the gall bladder is mainly found in ageing women, we therefore believe with Graham (1931) and Schornagel & Straub (1954) that cholecystectomy should be considered in all (long standing) cases of cholelithiasis over the age of forty

After this brief discussion of the relationship of gallstones to carcinoma of the gall bladder, we must now deal with some pathological features of cancer of the gall bladder

The sites of predilection of cancer of the gall bladder are, in order of frequency the fundus (54%), the neck (19%) and the wall adjacent to the liver (27%) (Vadheim *et al*) However it is often impossible to determine the site of origin particularly in advanced cases Carcinoma located in the two last mentioned places, in particular, invade the liver almost at once at autopsy the whole picture may *resemble massive* carcinomatosis of the liver

Irrespective of the type, carcinoma originates either in the superficial or in the deep epithelium of the gall bladder According to Ewing it first appears as a papillomatous proliferation a flat induration or an eroded ulcer That papillomas may themselves have carcinomatous properties is evident from the three cases in which malignant changes were observed by Vadheim *et al*

There is a definite correlation between the macroscopical

appearance of the tumours and their histological composition In the cases with a preponderance of tumour stroma (scirrhous) the tumours usually appear as firm, stony, shrunken masses, with remnants of the gall bladder contracted over the stones

The other type of tumour presents the exact opposite, i e a large bulky gall bladder usually adhering to the adjacent tissues either by adhesions or by fistulous tracts It is soft in consistency and mostly dilated Microscopically it is usually a medullar carcinoma because of the preponderance of cellular over stromal elements

The first type of tumour characterized as a shrunken mass is of a firm occasionally stony hard consistency Histologically this tumour usually proves to be an adeno carcinoma or a carcinoma a cellules independantes

Due to metaplasia portions of squamous cell carcinoma may be present next to the gland like tissue it predominates only in a small number of cases According to Gray and Sharpe (1941) plano cellular carcinoma accounts for about 4 5% of gall bladder carcinomas removed surgically

The second type of tumour soft and bulky in character is of a rubbery soft consistency and is white on the cut surface The lumen is generally filled with a putrefied mass due to necrosis usually associated with infection Perforation is therefore a quite common occurrence taking place either in the cystic duct the liver the anterior abdominal wall the duodenum stomach or transverse colon (Riedel 1911)

Histologically this tumour usually proves to be a carcinoma solidum (alveolare) an adeno carcinoma or a carcinoma a cellules independantes In the last mentioned case typical signet ring cells are often found these being large cells containing mucus with an eccentric nucleus

A papillar carcinoma extends into the lumen and does not invade the wall of the gall bladder until much later (Cooper 12%) It grows slowly and metastasizes at an advanced stage of the disease Necrosis may cause

haemorrhage Furthermore the growth may block the cystic duct Then as the result of the retention of blood and necrotic material in the gall bladder the tumour acquires a soft and bulky aspect

Von Hanseman and Broders introduced a "tumour index", which can be regarded as supplementary to the above classification Webber (1927), who adopted Broders method of classification for tumours of the gall bladder, expressed the degree of anaplasia of the tumour parenchyma in microscopical sections of the tumour on a scale of I to IV

In his series of cases Grade I and Grade II represent tumours which are only rarely of the bulky type, out of 14 cases only two palpable tumours belong to this group which contained no more than four instances of extension On the other hand 50% of tumours of Grade III and IV showed metastases, *while 12 out of 16 cases presented enlarged palpable gall* bladders (predominantly of the medullar type)

The grading of tumours is a personal affaire If done by the same pathologist, however, this grading may be a valuable aid in the choice of treatment and in the forecasting of the prognosis Vadheim *et al* observed that the incidence of metastases increased with advancing anaplasia In Grade I 25%, Grade II 64%, Grade III 88% and Grade IV 100 % of cases showed metastazation

Hence, the conclusion to be drawn from the statistical evidence at our disposal is that especially those tumours which appear as firm stony shrunken masses (scirrhous) when *originating in the fundus or the wall of the gall bladder*, can be regarded as a more favourable condition for surgical therapy than the bulky type (medullar carcinoma) Except where the development of the carcinoma concerned is papillary, this group of medullar tumours undoubtedly has an *adverse prognosis*

The first organ usually involved in cancer of the gall bladder is the liver Payr (1908) stressed the fact that, in most of the

early cases without macroscopically visible extension into the liver, there is nevertheless microscopical involvement. Vadheim *et al* reported macroscopical direct extension into the liver in 67.5% of his cases. Before starting an operation on the liver it is necessary to know which part of the organ is to be removed. That is why we studied the extent of the invasion of gall bladder carcinoma into the liver.

As noted previously (page 16), we found in our polyvinylite casts direct anastomosis between the subserosal venous channel of the gall bladder and the minor intrahepatic portal branches on either side of the fissura media. The former structures filled in retrograde motion via the latter, after injection of the portal vein and previous ligation of the cystic vein. In addition to direct extension of the tumour, there may be haematogenous spread to the liver via these channels. When studying similar preparations of livers invaded by the direct extension of the tumour, we observed that the affected area did not fill. All structures in these regions were completely occluded, either due to invasion or to external pressure. Only the major arterial branches of these areas were pressed towards the margin of the growth. Figures 97 and 98 demonstrate that the whole invaded area fails to fill. This region corresponds with the caudal regions of both paramedian lobes and part of the right lobe (see Ch. VIII).

If, with the introduction of new surgical procedures for carcinoma of the gall bladder, the possibility of this disease in the future is kept in mind, a number of cases still overlooked at present will no longer escape diagnosis. In Sainburg & Garlock's series the diagnosis was pre-operatively established in 23% of cases, though from Riedel's paper (1911) we gained the impression that this author achieved a much higher percentage with possibility of the disease in mind. At present even in relatively early cases the patient is usually inoperable by the method available, namely cholecystectomy. The progress of the disease, if the liver is involved, may definitely be

hastened by this procedure, as pointed out by Blalock (1924)

Aiga (1935) collected 10 cases reported in the literature up to 1935 of patients who had been well for periods ranging between several months and some years after the operation, and he added the case of one who had undergone cholecystec-

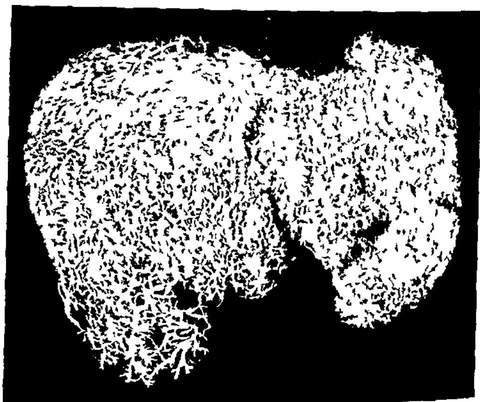


Fig 97 Corrosion specimen ventro-cranial aspect Notch caused by direct extension of carcinoma of the gall bladder

tomy for carcinoma more than 7 years prior to the appearance of his paper and who was still in good condition at that time This is an exceptionally rare case, however Suma & William (1947) reported on 47 cases of carcinoma of the gall bladder 23 were operated upon cholecystectomy was carried out in 6 Only 2 patients were alive at the time when their paper was

written, 3 and 6 years, respectively, following cholecystectomy. In both cases cancer was unsuspected at the time of operation, the true condition being only revealed by microscopic examination.

The above facts in general confirm the statement made by

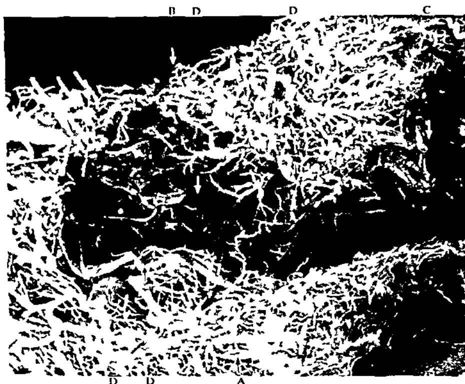


Fig. 98. Dorso-caudal aspect of the corrosion specimen in figure 97. Cavity caused by direct extension of carcinoma of the gall bladder. A, ventral side; B, dorsal side of the liver; C, proper hepatic artery; D, arterial stems situated on the border between tumour and liver tissue.

Kehr (1913), the pioneer of gall bladder surgery, when discussing his series of 2000 operations on the biliary system: 179 of these operations were for carcinoma and only 2 of these cases were cured "und das waren Zufallsheilungen, denn ich operierte nicht wegen eines Karzinoms, sondern wegen eines

Empyemas der Gallenblase und fand erst das Karzinom nachdem die Gallenblase aufgeschnitten war' ("and those were only chance cures, seeing that I was operating, not for carcinoma, but for empyema of the gall bladder, and did not discover the cancer until the gall bladder had been excised")

In some of the reported cases of carcinoma, *Riedel (1911)* even questions the diagnosis on the ground that "das Mikroskop getauscht hat und chronisch entzundete Gewebe mit Karzinomatosen verwechselt sind" ("the microscopist had been misled into identifying chronic inflammation of the tissue as a carcinomatous condition") In certain cases, such as proliferating glandular cholecystitis, it is undoubtedly difficult to differentiate with confidence between inflammation and a malignant growth

Only very few surgeons of the past ventured on a more extensive procedure as originally proposed by Payr (1908), namely, the removal *in toto* of the gall bladder with a wedge shaped part of the adjacent liver tissue Of recent years only a few isolated reports have appeared from Thorek (1947) Sheinfeld (1947) and Masse & Dubourg (1950), all attacking the liver in this old fashioned way

In Chapter X we shall describe how, on the basis of the anatomical findings in corrosion specimens of livers invaded by cancer of the gall bladder described in the present chapter, we decided on a radical operation in which the gall bladder is removed *in toto* with both paramedian lobes of the liver

B TRAUMATIC INJURIES OF THE LIVER

'In ancient times surgeons built up their experience in the workshops of war and war throughout the ages seems always to have served as a stimulus to advancement in surgical knowledge and craft' (Gordon Taylor, 1942) And it is indeed a fact that the battlefield surgeon sees a large contingent of liver wounds There are, for all that, many other causes of liver injuries In former times the kick of a horse was a notorious

one but at present, due to the increasing mechanization of traffic car accidents account for a great number of these injuries They may be due to compression, collision or crushing by the wheels, bumpers and steering wheel The over all risk of exposure to trauma has become greater in our time of ever increasing mechanization not only of transport but also in industry and agriculture Falls from a more or less great height are a relatively common cause Stab wounds shell and gun shot wounds either accidental or due to direct assault are occasionally encountered

Rupture of the liver in newborn children has been reported by Arden (1946), these infants were over mature and over sized

Hepatic rupture occasionally occurs in labour (Burton Brown *et al*, 1949) in association with toxaemia of pregnancy In this condition there is probably a predisposition to trauma

The incidence of trauma in civilian life—though increasing—constitutes only a minor fraction of the traumatic injuries of brutal modern warfare

In battlefield surgery its incidence is fairly high because of the large size of the organ Wallace s series shows a proportion of 16 8% of all the abdominal wounds for Liek s series (1915) this figure is 16 4% or 0 3% of all war casualties However, these figures are probably under estimations because they only refer to the casualties who survived transport from battlefield to hospital and who were operated upon

In war surgery we are generally dealing with penetrating percutaneous or perforating injuries, while the subcutaneous internal or non penetrating injuries are more common in civilian practice

The subcutaneous liver injuries form a small percentage of patients admitted to the traumatic services of hospital. In the series of Wright *et al* (1947) the incidence varied between 1 and 1 259% The age incidence in the Mikal *et al* series varied between 10 and 40 years

Elder (1887), in his study of 365 cases of subcutaneous injury of the solid viscera, reported involvement of the liver in 189 cases (52%) and of spleen, kidney and pancreas in 176 cases. In Wright's series, liver and spleen are injured in about the same number of cases; together they constitute 72% of all intra-abdominal injuries.

Both types, the subcutaneous and the penetrating injuries, will be described separately in a short discussion of the morbid anatomical features.

Subcutaneous injuries. The friability and the position of the liver combine to render this organ liable to direct and contrecoup injuries. In Mikal's series, the pars dextra hepatis was lacerated nearly five times more than the left lobe, and in Wright's series, even thirteen times. The larger and more laterally situated pars dextra is evidently more easily injured.

In contrast to the opinion of some authors who think the cranial surface of the liver the most susceptible part, in Mikal's series both the ventral and ventro-cranial as well as the dorsal surfaces of the liver were lacerated with equal frequency.

Laceration of the convex surface in a sagittal plane is probably the type most frequently encountered.

The idea that most ruptures take place along the dorso-caudal surface where the liver is pressed against the spine (O'Neill, 1934) is disproved by Wright *et al.*, among others.

Rupture of the liver may occur transcapsularly or subcapsularly. In the latter event the capsule is intact, in the former it is also ruptured. In the first case tamponading of the centrally or subcapsularly situated laceration will occur. This division into trans- and subcapsular does not take into account size and depth of the wound or the degree of involvement of total tissue, factors which as stressed by Martin (1947) are important for the prognosis.

Haematomas are formed in subcapsular lacerations but the

haemorrhage is tamponaded by the capsule and/or the adjacent hepatic tissue This is subsequently followed by abscess or cyst formation

The liver when injured transcapsularly shows a tendency to splitting and cracking in a stellate fashion usually accompanied by haemorrhage and cholerrhagia This bleeding is generally profuse and often tends to be persistent Wright *et al* summarized the causes of persistent bleeding, namely the friable liver tissue does not act as a tampon the diaphragmatic movements make the injury worse the spilled bile retards clotting and promotes infection and finally the thin walled intrahepatic veins do not possess valves and do not retract or contract

Our perfusion and injection studies showed that small lacerations already cause a massive leakage from the portal vein bed In deeply lacerated livers, leakage occurs from both portal vein bed and, to a somewhat lesser extent from the hepatic arterial branches The bleeding from the hepatic veins is only profuse during expiration as we observed during operation

In both subcapsular and deep transcapsular lacerations interference with the arterial and venous blood supply results in multiple infarctions, focal necrosis and sequestrations are common sequelae The surface of a fresh wound of the liver is ragged and blood stained within 24 hours it assumes a dirty yellow appearance as the result of local necrosis Later on it becomes bright yellow due to staining with bile (Hamilton Baily 1941)

In *percutaneous*, penetrating or perforating injuries of the liver the lacerations are usually commensurate with the size and the shape of the missile As regards gunshot injuries there is considerable controversy on the relationship between the distance from which the gun was fired and the extent of the damage (Liek) It is a certain fact that the shorter the distance

the greater the damage by both missile and explosion The whole organ can even be shattered by gunshot fired from nearby, but that the explosion is not alone responsible for the the damage done is evident from a case described by Liek (1915) in which the shot was fired from an infantry rifle at a distance of 80 metres, shattering the organ irreparably Complete fracture of some parts may occur, a considerable part may be detached, especially from the anterior edge, and may either lie free in the abdominal cavity or be carried away entirely from the body of the liver Fractured ribs and in driven ribs frequently cause serious hepatic trauma in addition to the injuries caused by missiles The greater the distance from which the shot is fired, the smoother is the channel bored and the fewer are the fissures radiating from it An hepatic abscess may develop around a retained missile, this ought to be removed if possible

Penetrating as well as subcutaneous injuries may be accompanied by *associated lesions* in other organs In perforating injuries other organs, such as the right kidney, adjacent viscera, pleural cavity, and lungs, may also be perforated, depending on the site of entry and the direction of the tract of the missile But as Busing (1920) demonstrated in two cases, it may be extremely difficult to determine the extent of the damage, even if both port of entry and port of exit are present This author advised exploration of the whole abdomen for perforation In 27 cases of perforating injuries Liek found 8 times associated injury to the right and once to the left lung once to the right kidney and once to the pancreas

In Mikal s series of cases with *subcutaneous* liver injury, the kidneys, spleen and lungs were involved in 20%, 10% and 17% respectively

We found the following statistics for the two World Wars In the First about 75% of the hepatic injuries were uncomplicated The mortality of uncomplicated liver wounds (in World War II) was about 10%, if one additional viscus was

injured, 28% and if two other organs were injured, nearly 40% (De Bakey, 1947)

The *symptomatology* of both the subcutaneous and the perforating injuries depends on the extent of the damage to the liver Though the latter is always followed by haemorrhage, shock is not present in all cases The blood that has escaped and occasionally the bile will, however, give rise to a peritoneal reaction Slight oozing causes some physical distress, with pain over the right hypochondrium radiating to the right or left shoulder (Kehr s sign) and with accelerated breathing

In the event of shock (as in 80% of Mikal s cases on admission) free fluid may be demonstrable in the abdominal cavity The abdomen becomes distended, usually accompanied by a rise of temperature and accelerated pulse, pallor restlessness and weakness These symptoms may however occur after a lucid interval varying between some hours and some days, in which case we are usually dealing with a secondary haemorrhage Biliary colics haematemesis and maleana may form part of the clinical picture (Rudstrom 1951 Epstein *et al*, 1952) Dullness in the right flank is an almost constant feature (Burnet *et al* 1950)

Bradycardia reported by some investigators (Finsterer 1910 and others) is not a common occurrence according to other authors (Wright and others) Occasionally a palpable mass is found which proves to be a subcapsular haematoma or a distended gall bladder, filled with blood If jaundice follows it does not become manifest until 48—72 hours after the injury

In all cases with a history of blunt trauma or penetrating injuries the chest should be carefully inspected for collapse of the lung due to pneumo thorax

Abdominal puncture if performed, must be done in all four quadrants (Wright *et al*) X ray examination may reveal an elevated diaphragm on the right side

Secondary manifestations may follow the initial symptoms

Complications such as sub phrenic abscess, cholerraghia, etc will be discussed in chapter XI At present we shall deal with only that form of hepatic failure which is known as hepato renal syndrome

The first published case of death from renal insufficiency after liver trauma is probably that reported by Furtwaengler (1927) Death ensued three days after the injury, an extensive diffuse epithelial degeneration was found in the convoluted tubules of both kidneys at autopsy

The symptomatology of the hepato renal syndrome is characterized by extreme hyperpyrexia, azotaemia, oliguria collapse with cold and moist cyanotic skin, hypotension, rapid thready pulse and delirium The urine usually contains erythrocytes, casts and varying amounts of albumen, anuria may follow, in which case the alkaline reserve is progressively depleted, leading to a lowered carbon dioxide combining power

Mason *et al* (1925) observed that small pieces of liver, cut *loose and put back into the dog's abdomen, rapidly* caused a fatal toxaemia The associated symptoms point to serious *injury to the liver and kidneys* A few grammes were sufficient to bring about death within 18—25 hours The same happened when small bits of liver tissue were inserted into the chest or axilla, peritonitis thus being excluded

MacDonald *et al* (1928) demonstrated that the liver protein was the responsible factor for these symptoms This liver protein is therefore believed to act as a toxic substance affecting both liver and kidneys (Helwig, Boyce)

The normal detoxifying function of a lacerated liver is impaired both by the trauma and the toxic action of *the de*vitalized liver tissue, while the renal damage is probably due to an increase of its normal *detoxifying duties*, which are increased by failure of the detoxifying function of the liver (Boyce) ***Removal of all devitalized liver tissue is therefore definitely indicated*** According to De Bakey (1947), 8 5% of deaths after

liver injury in World War II were due to associated renal failure

Not all untreated traumatic lacerations of the liver are fatal, as appears from a case reported by Fabricius Hildanus (early part 17th century) of a young man stabbed during a quarrel who suffered from a severe haemorrhage A large piece of liver later appeared in the wound and was removed by forceps The patient nevertheless recovered (Schroeder, 1906)

With the accumulated experience of Mayer Otis Edler etc however, the conviction has been gaining ground that immediate laparotomy with *control of haemorrhage* is imperative in the majority of traumatic liver cases

Ludwig Mayer who published the first report on hepatic trauma in 1872 found a mortality of 59% in the 276 cases which he collected Otis (1876) found a mortality of 62% in 181 cases observed during the American Civil War Edler (1887) collected 104 cases and in another series of 543 cases the mortality was 66 8% The mortality figures in these and in some recent series of cases treated without operation are Burnet *et al* 57 1% Wright *et al* 75–96% Mikal *et al* 81 8% That is why Mikal again recently advised operating immediately and controlling haemorrhage with the aid of gel foam oxidized cellulose, etc , because *of the high mortality in these series of cases treated conservatively*

The first case of traumatic liver injury successfully treated with control of haemorrhage was published by Von Burckhardt in 1887 From this time onwards surgical treatment has increasingly been accepted as indicated in these injuries

In 1896 Ferrier & Auvray reported the first series of 56 surgically treated cases of traumatic liver injury adding another 42 cases in 1901 The mortality was about 30% following suturing or tamponade of the laceration occasionally resections were carried out

As far back as 1910 Boljarsky observed an increase in the

mortality rate in proportion to the interval between the injury and its surgical treatment, consisting of *tamponade to control haemorrhage* Operation within 2–3 hours resulted in a mortality of 15%, after 4–5 hours of 40%, after 9–10 hours of 66 6%, after 12–14 hours of 83%, etc In other words, the longer the delay before exploration, the more adverse the prognosis for the patient In Mikal s series, surgery within the first three hours after admission led to a mortality of 33 33% rising after three hours to 66% All his patients appeared to be out of shock when operated upon

Sometimes the symptoms attending lacerations of the liver may be very confusing an early diagnosis being impossible In these cases, however it is being more and more accepted that exploration should be carried out " If we do not explore the patient, we may deprive him of his chance to live (Fairchild, 1931)

Hence agreement prevails as to whether one should or should not operate

Although the statistical evidence quoted shows that immediate laparotomy is indicated for this traumatic condition, mortality is still high, as Mikal *et al* has been able to show This in our opinion is due to the procedure adopted for controlling the haemorrhage, *viz* tamponade with or without suturing of the laceration

Considering the difficulties and risks to be faced during and after resection of parts of the liver until recently, this conservatism in surgical treatment is not surprising For all that *resection* is indicated in the event of deep lacerations

As early as 1920 Wendel remarked that there is no sense at all in tamponading or suturing the laceration so long as the surgeon has no information whatsoever about the vitality of the hepatic tissues located distally to the laceration Interruption of the blood supply to this area will result in gangrene and necrosis of the devitalized parts of the liver, as rightly pointed out by this author Man setzt den Tampon auf ein

Gewebe, über dessen Lebensfähigkeit man nichts weiss, nur um die Blutung zu stillen Nicht viel anders ist es bei schweren Rupturen mit der Naht Es kann keinem Zweifel unterliegen dass nach beiden Richtungen hin—Blutstillung und Zurücklassen nekrotisierenden zum Infektion geneigten Lebergewebes—die Leberlappenresektion viel günstigere Verhältnisse gibt (We tamponade a tissue, quite in the dark as to its viability for the sole purpose of controlling the haemorrhage And it is much the same with serious ruptures and a suture There can be no doubt at all but that resection of the hepatic lobes is far more satisfactory, both as concerns haemorrhage control and retention of necrotic readily infected liver tissue) (Wendel, 1920) This is all the more admirable as sound thinking in those days inasmuch as tamponade with or without suturing are generally accepted procedures to-day and are moreover constantly being advocated in current literature (Martin 1947 Mikal *et al* 1950, Scott 1951 etc) We feel we must therefore emphasize the imperative necessity for resection in deep lacerations, and submit that it is false medical thinking to depend solely upon antibiotics and blood transfusions for the prevention of complications such as haemorrhage, hepato-renal syndrome biliary peritonitis and subphrenic abscess

Chapter VIII

INTRODUCTION TO HEPATIC SURGERY

Since the introduction of surgery for hepatic pathology, most of the attention has been centred upon the problems involved in the control of haemorrhage Tinker (1905) stated that

> oozing is apt to be perfuse and persistent with ordinary cutting methods The liver tissue is friable and frequently does not hold ligatures or sutures particularly well Large vessels embedded in the liver substance are sometimes difficult to pick up with artery forceps to tie readily The many methods of controlling haemorrhage which have been used indicate that there is no single infallible method

We shall briefly discuss the various methods adopted in the past for the resection of sections of the liver and the attempts made to control haemorrhage

Removal of pathology with the aid of *thermocautery* (Escher 1880) soon proved to be harmful because of the danger of secondary bleeding after demarcation of the eschar, the frequently insufficient control of haemorrhage and the fact that this coagulated tissue may invite infection (*fig 99*)

Garre (1907) rejected thermocautery because of its incompetence to control haemorrhage from the larger sized vessels while the charred liver surface hindered the surgeon from grasping the individual veins

Radiocutting has been considered less destructive than actual

cautery because it cuts much faster, however it is hardly efficacious in arresting oozing and worthless in severe bleeding Anschutz (1903) advocated the blunt division of the liver which recently was applied again by Quattlebaum (1953)

Elastic ligature compression of the stump is one of the oldest procedures (Couzins 1874) sometimes this tourniquet was held in place by fixation pins, while the stump was extra peritonealized This method has long since been discarded because of the slow healing and the risk of infection

Tamponade of the raw liver margins following resection as advocated by Anschutz (1903) initially with iodoform gauze (Mickulitz) soaked in warm saline to which adrenaline was added, is a method now probably practised by no one Yet in those days some surgeons came to the conclusion (*e g* Ransohoff 1904) that immediate closure of the laparotomy wound ought to be rejected unconditionally The abdomen was therefore left open over the packed liver area To tamponade gunshot tracks Schroeder (1906) even devised a rubber bag which could be inflated after its introduction into the tract of the missile

During World War II good results were attributed to the use of pieces of macerated muscle as a tampon which was applied to or sutured on the bleeding surface It was thought that a haemostatic agent was liberated from this muscle promoting arrest of the bleeding All sorts of grafts have been advocated omentum (Boljarski 1910) tendons the falciform ligament, the gall bladder (Wendel 1911) etc In all kinds of lacerations tamponade of the wound with gelatine sponge or oxidized cellulose soaked in thrombine is at present a generally accepted procedure (Scott 1951)

Rubber covered clamps, especially the Doyen clamps have been used and advocated by Garre (1907) McDill (1912) and others Initially these clamps were left on the liver for 24 to 48 hours for which reason the abdominal wound had to be left open (Clement 1890 Kocher 1902) This procedure

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Since the introduction of surgery for hepatic pathology, most of the attention has been centred upon the problems involved in the control of haemorrhage. Tinker (1905) stated that "oozing is apt to be perfuse and persistent with ordinary *cutting methods. The liver tissue is friable and frequently does* not hold ligatures or sutures particularly well. Large vessels embedded in the liver substance are sometimes difficult to pick up with artery forceps to tie readily. The many methods of controlling haemorrhage which have been used indicate *that there is no single infallible method*."

We shall briefly discuss the various methods adopted in the past for the resection of sections of the liver and the attempts made to control haemorrhage.

Removal of pathology with the aid of *thermocautery* (Escher 1880) soon proved to be harmful because of the danger of secondary bleeding after demarcation of the eschar, the frequently insufficient control of haemorrhage and the fact that this coagulated tissue may invite infection (fig. 99).

Garrè (1907) rejected thermocautery because of its incompetence to control haemorrhage from the larger sized vessels *while the charred liver surface* hindered the surgeon from grasping the individual veins.

Radiocutting has been considered less destructive than actual

cautery, because it cuts much faster, however it is hardly efficacious in arresting oozing and worthless in severe bleeding Anschütz (1903) advocated the blunt division of the liver, which recently was applied again by Quattlebaum (1953)

Elastic ligature compression of the stump is one of the oldest procedures (Couzins, 1874) sometimes this tourniquet was held in place by fixation pins while the stump was extraperitonealized This method has long since been discarded because of the slow healing and the risk of infection

Tamponade of the raw liver margins following resection as advocated by Anschütz (1903) initially with iodoform gauze (Mickulitz) soaked in warm saline to which adrenaline was added is a method now probably practised by no-one Yet in those days some surgeons came to the conclusion (*e g* Ransohoff 1904) that immediate closure of the laparotomy wound ought to be rejected unconditionally The abdomen was therefore left open over the packed liver area To tamponade gunshot tracks Schroeder (1906) even devised a rubber bag which could be inflated after its introduction into the tract of the missile

During World War II good results were attributed to the use of pieces of macerated muscle as a tampon which was applied to or sutured on the bleeding surface It was thought that a haemostatic agent was liberated from this muscle promoting arrest of the bleeding All sorts of grafts have been advocated omentum (Boljarski, 1910) tendons the falciform ligament the gall bladder (Wendel 1911) etc In all kinds of lacerations tamponade of the wound with gelatine sponge or oxidized cellulose soaked in thrombine is at present a generally accepted procedure (Scott 1951)

Rubber covered clamps especially the Doyen clamps have been used and advocated by Garre (1907) McDill (1912) and others Initially these clamps were left on the liver for 24 to 48 hours for which reason the abdominal wound had to be left open (Clement 1890 Kocher 1902) This procedure

has been discarded because of the danger of infection Though the clamps are still used, they are now taken off after suturing the raw liver margin *after the resection* Then liver edges are preferably compressed digitally

A variety of *hepatic sutures* have been advocated, all being *modifications of that favoured* by Kusnetzoff and Pensky (1896) A large blunt needle was used to prevent injury to the vessels, threaded with a double piece of heavy catgut, one of *the threads of* which was cut after the needle had passed through the liver tissue and was then tied After division of the liver, the large vessels were circumstitched in the cut surface

The disadvantage of 'cutting through' of these sutures was avoided by the application of magnesia plates, introduced by Payr & Martina (1905) These were narrow perforated plates, consisting of pure magnesia of variable length fastened along the line of resection against the ventral and dorsal liver surfaces by means of heavy catgut When the catgut had been tied the raw liver margins were coaptated, if possible

Wendel (1911) introduced an interlocking type of mass ligature which he applied in a resection of the right liver half for a primary cancer of the liver *Before resection, he ligated the right hepatic artery and right hepatic duct* but refrained from ligaturing the right portal vein trunk for fear of thrombosis The patient was well for over 9 years after the operation

This is as far as we could trace one of the very first surgical

Fig 99 Major methods of resection

1 Elastic ligature and extraperitonealization of the stump ([illegible] 1874) 2 Simple cautery (Paquelin) removal ([illegible] 1886) 3 *Lobectomy with reported* less bleeding for physiologic line of cleavage used (Langenbuch 1888) 4 *Hemostatic suture with blunt needle and closure of liver surfaces after resection* (Kousnetzoff and Pensky) 5 Clamps left on for hemostasis and (a) completely exteriorized (Lapoint 1897) or (b) only the handles exteriorized for removal through a stab wound (Kocher 1902) 6 Excision with tamponade (Anschutz 1903) 7 *Hemostatic sutures* placed proximal to clamps and electrocautery excision of tumor distal to clamps Raw surface closed by *interrupted* sutures going around the longitudinal hemostatic sutures preventing cutting of sutures through liver tissue (Warvi, courtesy of *Surg Gyn and Obst* [illegible] 13 1945)

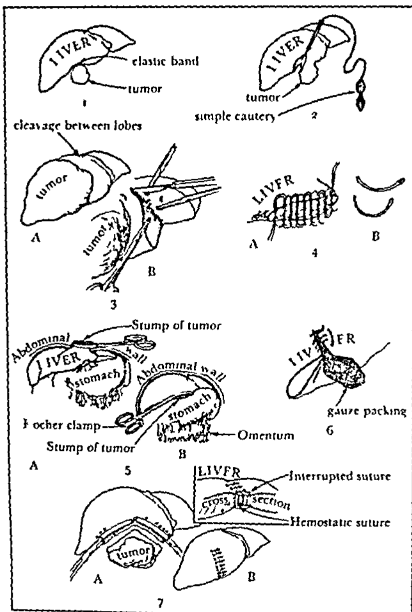

LIVER
elastic band
tumor
1
LIVER
tumor
simple cautery
2
cleavage between lobes
tumor
A
tumor
B
3
LIVER
A
4
B
Stump of tumor
Abdominal wall
LIVER
stomach
Abdominal wall
stomach
Kocher clamp
Omentum
Stump of tumor
A
5
B
LIVER
gauze packing
6
LIVER
Interrupted suture
cross section
Hemostatic suture
tumor
A
B
7

Fig. 99

procedures performed along an avascular plane of the liver through fossa cystica and fossa venae cavae with control of bleeding at the hilum, which is in sharp contrast to the *bloodless form of surgery*, advocated by Baron (1910), Wangensteen (1951) and others, where by the hepatic artery and portal vein were compressed during surgery in the hepato duodenal ligament

Comparatively early, both Keen (1897) and Langenbuch *(1897) realized that the fossa sagittalis sinistra of Von Haller* should be regarded as a relatively avascular plane, along which they resected the "right or left liver lobe'

Keen, Langenbuch and Wendel therefore have a legitimate claim to being the pioneers of an anatomically sound form of hepatic surgery Wendel went a step further than Keen and Langenbuch, who had for long been resecting along an avascular plane, when he first ligatured the structures at the hilum

Keen's work, among these authors was generally known and adopted, in fact until quite recently, there had been little advance since Keen described his operation (1899) in which the left liver lobe was severed with a Paquelin cautery and the larger veins were closed with the tips of the finger following which the cautery was temporarily laid aside I passed a catgut ligature under each vein by means of a Hagdorn needle, and one of my assistants tied slowly but firmly Five ligatures were thus applied ' A packing was applied which was removed after 48 hours "No haemorrhage occurred, but bile escaped to a considerable extent from the 4th to 12th day (Keen)

In surveying all the methods advocated, one is not surprised to learn that nearly every case of liver surgery, if the patient survived has appeared in the literature This in itself proved how risky these surgeons considered this procedure and how lucky they felt that the operation did not end fatally (Bax & Schalm 1954)

Judging from the number of cases reported it appears that around 1910 hepatic surgery enjoyed more interest than at any other time. The number of cases however gradually decreased and after 1920 reports were no more than sporadic. For this reason we have no hesitation in saying that this form of hepatic surgery never became popular, even though Warvi (1945) tried to re-introduce the best techniques of all the old methods.

The principle of the *new form* of hepatic surgery which we are about to describe is based on a thorough knowledge of the anatomy of the organ, in contrast to the various forms summarised above.

At first it was thought that the problems could be solved by *technical* means, without taking account of the intrahepatic structures, the only exceptions being the three authors mentioned, *viz.* Keen, Langenbuch and, more especially, Wendel; and those few who had adopted Keen's technique. But the general rule was to resect areas of the liver regardless of their relationship to the totality of the organ and without foreknowledge of injury or otherwise or ligaturing structures afferent to or efferent from distal liver areas, which as a result remained behind often devitalised after the resection.

As Martin (1947) has pointed out, repair is retarded when major amounts of liver tissue are devitalised until full sequestration occurs. The devitalised tissue not only increases the risk of primary haemorrhage but also of cholerrhagia and secondary haemorrhages liable to occur during sequestration. In a subsequent chapter (XI) we shall consider other complications apt to be produced by the presence of devitalised hepatic tissue, *viz.* infection (abscesses), hepato-renal syndrome and the like.

It is owing to these facts collectively and individually that none of these techniques ever became popular.

As we have seen, Wendel* was the first to practise well

* Among Wendel's references we found Thole, to whose work we were not able to have access.

informed anatomically sound surgery Cantlie (1898) already had demonstrated "*that the gallbladder occupies a central* position in the liver, that on either side of it lie the true right and left lobes of the liver and that a line from the fundus of the gall bladder to the exit of the hepatic veins divides the liver into equal portions", a conclusion independently confirmed by Wendel and Martens (*1920*)

These two authors realised that resection on one liver half *should* be performed along the vascular plane through gall bladder fossa and vena cava inferior, following ligation of the unilateral structures at the hilum of the liver, especially since Wendel had obtained such excellent results in a patient whom he operated upon in this way (1911) for what initially appeared *as an adenoma, but 9 years later at autopsy proved to be a* hepato cellular carcinoma

As far as we have been able to trace, no surgeon ever applied this principle between 1911 and 1952, till finally this procedure was re introduced by Seneque *et al* (1952), who performed a left hemi hepatectomy for hydatid cysts

Meanwhile, anticoagulants had become available since 1911 liberating ligation of one of the trunks of the portal vein from the risk of thrombosis Intrahepatic mass ligature had thus become superfluous, seeing that ***bleeding could be controlled from the hilum*** by there ligating the unilateral structures prior to resection Others had sought to solve the problem along *similar lines*

There was Raven (1949), for instance who had worked out an operation for the resection of the left hepatic lobe after ligaturing the structures to the hilum He ligatured to the hilum the left trunk of the portal vein the left hepatic artery and the left hepatic duct after which he resected the left lobe of the liver by thermocautery This procedure however, falls *short of the* best anatomical and physiological standards in that it leaves the left paramedian lobe devitalized

After ligaturing the right hepatic duct the right hepatic

artery and the right trunk of the portal vein, Fortat Jacob and Robert (1952) resected the right half of the liver together with the quadrate lobe. Although the resected parts do not correspond perfectly with the internal morphology of the organ, as Couinaud (1953) justly observed, their work attracted attention for the sound novel methods it introduced into hepatic surgery.

We, for our part are persuaded that these authors were stimulated by the latest developments in lung surgery to adopt the procedure of ligaturing the various structures to the hilum of the liver before proceeding to resect. By the same token Couinaud, Healey and we ourselves, inspired by the benefit accruing to modern pulmonary surgery from a thorough study of the anatomy of intrapulmonary hollow structures have pursued an analogous course for hepatic surgery.

The legitimate inference to be drawn from anatomical research *in the interests of surgery is that rather than one* there are *two* hepatic gateways, each with its own specific significance. For in addition to the hilum we have the point at the cranial pole of the liver where the hepatic veins leave the organ. As has been shown, the veins there can be dissected for some distance. The plane in which the veins lie *the dorsal fissure* (see figs 12–14 and 101–103), separates the ventral and dorsal paramedian lobes. Not only do these veins mark off the dorsal fissure, but, as we have stated before, they proceed from there to the three sagittal interlobar fissures by which the various Glissonian areas are bounded.

These fissures are ideal planes for the resection of parts of the liver firstly because incision along these planes is itself a safeguard against the notorious complications attendant upon the classical form of surgery *i e the risk of haemorrhage,* cholerrhagia and occlusion of those structures which are distal to the plane of resection possibly involving other very real dangers (see Chapter XI) in addition to morphological or

functional loss of hepatic tissue, secondly because, even if these planes are not always visible on the surface, the major hepatic veins, by their very position, mark them off

These planes are avascular—except for the hepatic veins situated within them and the hepatic venules which may pass across them—and contain no portion of the bile ducts It has been found in actual surgery that, by opening the liver along *these planes*, haemorrhage is avoided, provided the hepatic veins or venules be left intact Technically, this is a very simple matter, as we had occasion to note with Bax in dogs and later with Pernet, during a hemi hepatectomy, using the method introduced by Anschutz (1903) and recently recommended again by Seneque *et al* (1952) and Quattlebaum (1953), which consists in *incising the liver bluntly!* In this way one can be sure of not opening the hepatic veins which intersect the plane These small vessels can be dissected, for which we used the handle of the scalpel, afterwards ligaturing them individually

The importance of these planes warrants a closer description of them with reference to figs 12–14 and 100–103

The *left interlobar fissure* cuts the ventral surface of the liver along a line corresponding to the connecting line between the umbilical incisure and the left wall of the caudate lobe The plane through this fissure passes along the left lateral wall of

Figs 100–103 Corrosion specimen of a liver All structures of Glissonian system injected

Fig 100 Ventral aspect of the liver

Fig 101 Same specimen as fig 100 Right paramedian lobe removed 1 Right paramedian vein 2 Right vein 3 Sagittal part of left stem of portal vein 4 Left cranial paramedian vein 5 Plane of intersection through left interlobar fissure 6 Plane of intersection through right interlobar fissure 7 Front view of caudate lobe 8 Vessels of the gall bladder (injected via cystic artery and cystic vein)

Fig 102 Same specimen as fig 101 Left paramedian lobe removed 4 Left cranial paramedian vein 9 Saccus 10 Left caudal paramedian vein

Fig 103 Same corrosion specimen as fig 102 Cranial segments of right and left lobes removed

11 Cranial vein of left lobe 12 Caudal vein of left lobe

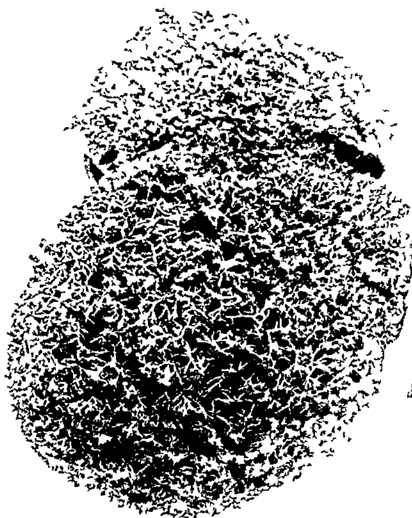


Fig 100 For legend see page 160

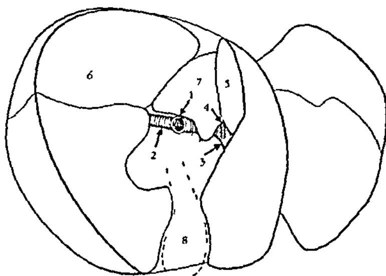


Fig 101 For legend see page 163

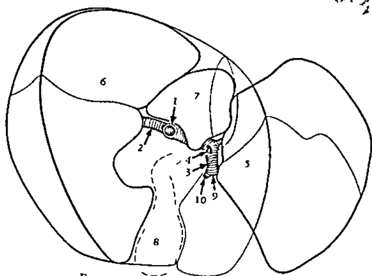


Fig 102 For legend see page 160

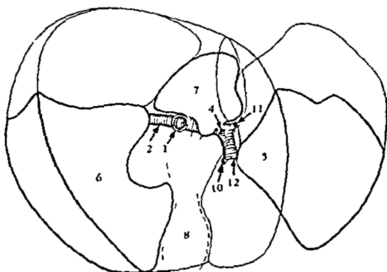


Fig 103 For legend see page 160

the vena cava inferior, hence it is not perpendicular to the horizontal plane which can be imagined as passing through the hilum, but forms an angle with it varying from 45° to 75°, with the mouth of the angle turned to the left Thus the plane through the fissure runs roughly parallel to that through the medial fissure

The plane of the left interlobar fissure cuts the sagittal part of the left portal vein into two halves, a medial half from which the left cranial and caudal paramedian veins arise and a lateral half from which come the cranial and caudal veins of the left lobe

The left interlobar hepatic venule which marks off the plane of the fissure, runs ventrally to the sagittal part of the left portal vein The calibre of this vessel is usually considerable Any resection of areas medial to this vein (e g middle hepato lobectomy or the resection of the pars dextra hepatis) should spare this vein as it almost exclusively drains blood from the left lobe of the liver (see fig 82)

In sum then the plane of this fissure can be fairly simply defined with reference to the following points the connecting line between the umbilical incisura and left lateral wall of the caudate lobe the left lateral wall of the vena cava inferior and the left interlobar hepatic venule

As we have already been able to establish (Chapter VI) *the left lobe of the liver is an hepatic lobe in a surgical as well as anatomical sense in that it possesses its own afferent and efferent structures* The Glissonian pedicles are found in the umbilical fossa and the hepatic vein pedicle (left hepatic vein) is in between the two leaves of the coronary ligament (fig 80 p 94)

The *medial fissure* cuts the ventral liver surface along a line described by Cantlie as running from the fundus of the gall bladder to the exit of the hepatic veins The plane of this fissure is demarcated by the middle hepatic vein the most

proximal part of which is situated in the line on which the medial fissure and the dorsal fissure intersect, thus cutting not only the left half of the liver off from the right half, but also the ventral middle lobe *from the dorsal*

The middle hepatic vein drains the blood from the middle lobe, except from the dorso lateral area of the 'dorsal fin' *Hence the middle lobe is a liver lobe in both an anatomical and a surgical sense, because it has its own afferent and efferent structures at both gateways*

The *intermedial fissure*, on the other hand, which cuts the right paramedian lobe into two parts, *viz*, the areas of the ventral and dorsal fin, has no surgical value It is for this reason that *we do not regard these two areas as segments, for they have* neither their own segmental Glissonian pedicle, nor an intrinsic blood drainage Hence this contrasts with the two segments of the left lobe of the liver

The *right interlobar fissure* is less readily identified at the surface of the liver than the fissures referred to previously The right hepatic vein is situated in the plane of the fissure rather more frontally than sagittally The fissure divides the right paramedian lobe from the right lobe Usually the fissure intersects the *right lateral wall of the cystic fossa*

Before proceeding further, we would do well to consider the variability of the position of this fissure It was stated in Chapter I that the right interlobar fissure seldom cuts the dorsal surface of the liver along the line indicated by Healey *et al* and *Couinaud but is inclined rather to follow* a line which usually approaches or cuts the cystic fossa This would account for the fact that in carcinoma of the gall bladder, the right paramedian lobe as well as the caudal segment of the right lobe is affected The part of the right lobe which is attacked by this disease consists of a thin slab of hepatic tissue In many cases it seems to us unnecessary not to say inadvisable to

remove the whole right lobe merely for the sake of this small section, in other words to perform a resection of the pars dextra We have therefore made a special study of this area with the



Fig 104 Specimen of the Glissonian system dorsal aspect A fossa cystica B venae paracysticae

help of thirty corrosion specimens the results of which will now be related

The condition we found in 60% of our specimens was as illustrated in figs 12 and 104 It will be seen that usually one, but sometimes two paracystic veins issue from the vena dextra before it bifurcates into the cranial and caudal veins of the right lobe The area of ramification of the paracystic vein

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corresponds to the medial area of the caudal segment of the right lobe and covers the same ground as that assigned by Healey *et al* and Couinaud to the right paramedian lobe The paracystic veins which in this group of specimens may arise from any point situated between the origin of the right



Fig 106 Glissonian system specimen dorsal aspect Both right and paracystic vein absent A vena caudalis lobi dextri B fossa cystica

paramedian vein and bifurcation of the vena dextra—a distance which proved to vary from 1 cm to 5 cm—can be visualized either from the right incisura or along the vena dextra after the liver has been opened bluntly (see p 174)

In 40% of the specimens there was no paracystic vein at all



I g) , Specimen of the (l n an system dorsal a pect The paracystic ve n
s absent be ng part of the dorsal fan A f n a cyst ca

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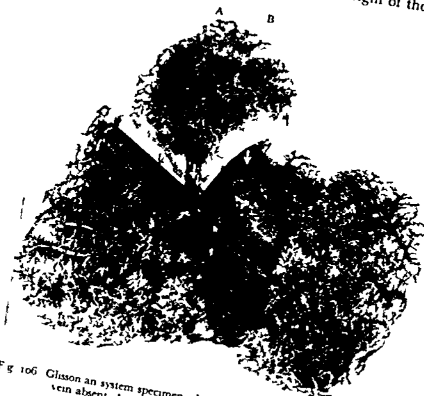


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and in 10% this was found to be due to the fact that the vein formed part of the dorsal fan It was only in this group of 10% that the right interlobar fissure cut the dorsal surface of the liver as reported by Healey *et al* and Couinaud (see figs 18 19 and 105)

In 30% of the specimens the absence of the vessel was accounted for by the fact that the vena dextra was lacking In a case of this kind, the right trunk (see fig 106) divides into three branches, one, the right paramedian vein, in a ventro caudal or ventral direction, one, the caudal vein of the right lobe, in a lateral or latero caudal direction, and the third, the cranial vein of the right lobe, in a lateral or latero cranial direction *

In all these specimens the right interlobar fissure either cut the right wall of the cystic fossa, or ran along the lateral wall of the cystic fossa

The surgical implications of these facts are that, prior to resection of the middle lobe for early gall bladder carcinoma, it is necessary to ascertain the course of a paracystic vein If there is one, it should be ligatured, as the area of ramification of this vein has to be included in the resection

Now, the boundaries of this area to be resected can seldom be established with absolute certainty beforehand What the surgeon does know during resection, after the paracystic vein has been ligatured, is that he is working within those boundaries if incision does not provoke bleeding But if haemorrhage does occur, it may be taken as a warning that the border of this area has been violated and in that case the best procedure is to resect the whole caudal segment of the right lobe *in toto* with the middle lobe

In the absence of the paracystic vein, a middle lobe resection will suffice in the first stage of carcinoma of the gall bladder If, on the other hand *the vena dextra is lacking* the alternatives are either to resect the caudal segment of the right lobe

* An insight into the anatomy of the intrahepatic portal venous system may be gained by means of a portal venogram (see Appendix II)

in toto with the middle lobe after ligaturing the segmental pedicle, or to resect the pars dextra in its entirety

It should furthermore be pointed out *that the right lobe, like the middle and left lobes, is a lobe of the liver both anatomically and surgically for the reason that intrinsic to it are a Glissonian pedicle and an hepatic vein stem*

The various structures of the Glissonian and of the hepatic vein systems can usually be dissected from the three lobes as well as from the two halves of the liver both at the hilum and at the upper pole of the liver At the latter this is a fairly simple matter the anterior leaves of the triangular and coronary ligaments are incised at the caudal point of transition to the falciform ligament By dissecting straight along the dome of the liver, the vena cava inferior is reached and here the three main stems can be exposed (fig 80) The corresponding vein allied with the hepatic lobe to be resected can be followed intrahepatically for some distance as we did with dogs with impunity

In two of our dogs the abdomino-thoracic approach was used After ligation of the cystic duct and cystic artery the Glissonian pedicles of the middle lobe were followed into the liver the overlying liver tissue being incised bluntly No bleeding occurred These structures were ligated intrahepatically at the desired place

Then the corresponding hepatic vein was identified at the cranial pole of the liver This main hepatic vein and several of its branches *were dissected bluntly over the whole length* in a caudal direction There was some slight oozing but this had completely stopped at the time the abdomen was closed The hepatic vein was ligated intrahepatically under direct vision at the same level where the Glissonian pedicle had been ligated beforehand The middle lobe was removed *en bloc* with the gall bladder

Both dogs did very well post operatively They were sacrificed three months after the operation The only signs of previous surgery observed at autopsy were the absence of the gall bladder and the fixation of the omentum which had been approximated to the cut surface (fig 107) There were no signs of portal vein thrombosis and no visible traces of the extensive dissections at the hilum or in the body of the liver



Fig. 107. Dog's liver seen ventro-cranially. Adhesions in the area of the resected middle lobe. Remaining lobes thickened and with rounded margins

It is necessary to bear in mind that the walls of these major hepatic veins are very thin and may easily be torn. They should, therefore, not be clamped (Bax, 1954). The course of the interlobar or resection plane—whichever the case may be—can be determined by the course of these veins, if not altogether, then at least part of the way.

In view of the important role played by the hilum in hepatic surgery, we think it would be appropriate to recapitulate briefly the main points of the topography of the various structures referring to Chapters III and IV for a more detailed description.

As we have seen, conditions at the porta hepatis are far more intricate. Accordingly, Couinaud favours approaching the hilum, not only dorsally as he advised at first, but ventrally at need. He was induced to take this line by 'certaines critiques (qui) ont été formulées concernant leur possibilité et leur innocuité. Il semble que « le nombre des variations segmentaires ait suscité de légitimes alarmes; comment sur des faits soumis à d'aussi nombreuses variantes construire une technique simple susceptible de faire face à des dispositions aussi diverses? » (some criticism made as to their possibility and innocuousness. Apparently the number of existing segmentary variations has legitimately raised some alarm. How can a simple technique, capable of coping with such diversity, be based upon facts subject to so many variants?)

For the frontal approach to the hilum, Couinaud reverses the normal method by which the lobar structures are first picked out at the two hepatic gateways and ligated, after which the liver is incised. He first incises the liver along an interlobar fissure and ligatures the lobar Glissonian pedicle intrahepatically, or he opens the fissure until the part to be resected is attached only to the Glissonian pedicle, after which this is ligated. Thus, in a hemi-hepatectomy, the liver is incised along the medial fissure down to the hilum and in this way *the hilum is approached from the front*. To our mind, the

drawback to this procedure is the considerable haemorrhage from the plane of resection which occurs after the hepatic venules crossing this plane have been ligated. For, as the afferent structures at the *hilum have not yet received* attention, there is a rise in the intrahepatic blood pressure in the hepatic veins. The consequent bleeding is liable to obscure the area being operated upon. For all that, there may sometimes be advantages in adopting this route in preference to *the caudal hilar approach*, as in those cases mentioned by Couinaud, *viz.*, tumours in the region of the hilum—a condition which we personally consider as inoperable—or adhesions of the liver to adjacent tissue.

There is, however, an alternative, which surgical treatment of dogs brought to our notice. It consists in enlarging the hilum in the course of the branches of the portal vein, a decided asset especially on the right side, if there is no right incisura, or only a small one (in about 20% of all livers[1]). It means that a right incisura can be made by enlarging the hepatic gateway from *the edge of the hilum. Given a blunt incision in the produced* part of the right trunk of the portal vein and the right vein and provided penetration into the liver be not too deep, haemorrhage is virtually obviated. The hilar edges are held to one side by means of eyelid retractors (modification Desmarres). *In this way even the right vein, which runs fairly super*ficially under the dorsal surface of the liver, can be followed to where it divides into the segmental branches, *viz.*, the cranial and caudal veins of the right lobe.

There are practically no large or medium branches of the *hepatic vein at this site*, at most a few minute capillaries may be encountered. This is because the surface area around the hilum discharges blood into the venae hepaticae breves which run almost parallel to the right trunk or the *vena dextra* (fig. 88).

Adopting this method of enlarging the hilum one can, for instance, dissect the paracystic vein(s), should this be im

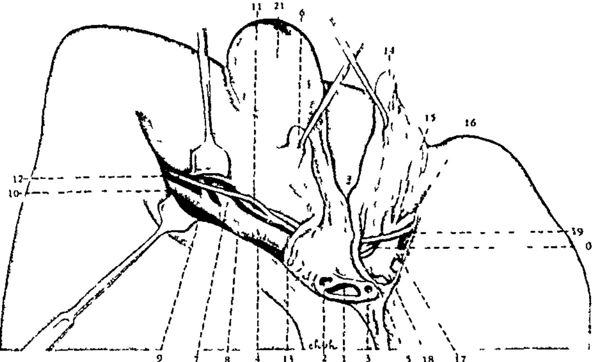


Fig. 108 Topography of the hilum of the liver Prepared specimen of Glisson's capsule (6 and 14)
1 Common portal vein 2 Bile duct 3 Proper hepatic artery 4 Right stem of portal vein 5 Left curvature of portal vein *Right* 7 Right paramedian vein (stretched in caudal direction by retractor) 8 Cranial vein of right lobe 9 Lateral vein 10 Caudal vein of right lobe 11 Right paramedian artery 12 Right artery 13 Right hepatic duct *Left* 15 Paraumbilical vein 16 Caudal vein of left lobe 17 *Intermedian vein of left lobe* 18 Cranial vein of left lobe 19 Caudal artery of left lobe 20 Left paramedian duct 21 Gall bladder

practicable in the hilum, itself, as well as some of the other territorial structures

Portal vein Each individual lobar portal vein branch can be visualized at the liver hilum In the left half of the hilum (*umbilical fossa*), even the segmental branches can be identified over a considerable distance before they disappear into the liver However, in the majority of cases the left paramedian cranial vein, if it arises from the ventral surface of the pars sagittalis cannot be reached Visualization of the segmental branches supplying the left liver lobe can be realized by incision of Glisson s capsule in the umbilical fossa along the dorso medial margin of the left liver lobe, till after further preparation these branches appear at the bottom of the umbilical fossa (fig 108)

A similar course can be adopted for the preparation of the territorial branches of the left paramedian lobe, the caudal branches (*left paramedian caudal branches*) at the medial aspect of the saccus can always be seen, the cranial ones are visible in only 35% of the cases (namely when they arise from the medial instead of the ventral surface of the sagittal part of the left portal vein) after proper dissection Therefore the capsule should be incised along the dorso lateral margin of the quadrate lobe

Disregarding the condition in which the right portal vein trunk divides at its very origin (bifurcatio venae portae), when the right paramedian vein is the direct continuation of the main portal vein trunk (20%), and the condition which was encountered in 10% of the specimens, in which the right paramedian vein originates from the left portal vein it may be said that this branch generally arises right at the margin of the right hilum Incision of the capsule along the right hilar margin and right incisure and retraction of the overhanging liver edges at this site generally enabled us to visualize both the right paramedian and the right vein After removal of the

enveloping connective tissue of Glisson s capsule the right paramedian vein can be followed intrahepatically for a distance of at least 1 cm The same holds true for the vena dextra distal to the origin of the right paramedian vein

Hepatic artery In upper abdominal operations such as gastrectomy ligation of an aberrant hepatic or accessory hepatic artery —which if no anastomoses between this vessel and the branches of the proper hepatic are present at the hilum are endarteries for the liver areas supplied by them— may result in necrosis of these areas (lobes or segments) if no antibiotic treatment is instituted This may explain at least some instances of liver death reported after upper abdominal surgery

On the other hand Segall while discussing the numerous anastomoses between the intrahepatic branches of the hepatic artery and the phrenic arteries by way of the coronary ligaments and the hepatic capsule pointed out Ligation of the hepatic propria distal to the origin of the arteria gastrica dextra when the hepatic artery is previously healthy results in more or less extensive necrotic changes and eventually necrosis is a probable outcome that must be feared But if the artery is diseased then it is permissible to ligate at this point with freedom from fear of untoward results because one can count upon a previously developed collateral circulation

A number of hilar dissection specimens were compared with ae plastic casts These comparative studies brought to light a rule of great importance to hepatic surgery namely that the intrahepatic distribution of the different branches of the left hepatic artery can be predicted from their location at the hilum provided that their extrahepatic course has been partly visualized by dissection It is therefore necessary to trace the artery to the site where it penetrates into the body of the liver tissue

Immediately before entering the liver the arterial branch joins the

corresponding portal vein branch and bile duct in the umbilical fossa or left hilar area

This fact holds true for the arterial branches supplying the left liver lobe, the caudal area of the left paramedian lobe and the caudate lobe The branches for the left lobe finally join the cranial and caudal left lobar veins at the place where these two (occasionally three if an intermedial vein is present) enter the liver, they can be visualized in the same way as previously described for the portal vein branches The left paramedian artery, usually coursing medial to, occasionally dorsal to the pars sagittalis venae portae, can be seen disappearing into the caudal area of the left paramedian lobe after joining the corresponding vein and bile duct at the medial aspect of the saccus Rarely, if ever, can the cranial arterial segmental branch be recognized as such

On the right there are two anatomical features of surgical significance, *viz*

(1) An arterial branch, usually the arteria dextra but sometimes a segmental branch, curves around the basis of the *right paramedian vein during its lateral course An anterior* relationship, in which this artery curves over the basis of the right paramedian vein, was found in 80% of the specimens while a posterior relationship, with the artery curving underneath the basis of this vein, was present in 20% of the specimens (13% in Couinaud s series)

(2) The right paramedian artery usually runs along the *medial aspect of the corresponding vein, namely in* 78% of our specimens (65% of Couinaud s specimens), but occasionally along the lateral surface (18%), anterior surface (2%) or posterior surface (2%) of this vein Sometimes two (10%) or even three (2%) arteries are present running along this vein

While dissecting the right paramedian vein from its Glissonian tissue the surgeon should beware of injuring the branch curving around the basis of this vein Only the visible structures

are dealt with when resection of the right paramedian lobe begins The right paramedian artery, running along the medial surface of the corresponding vein, is divided between ligatures (mounted on a Deschamps suture carrier), after which the corresponding vein is treated in the same way By leaving the ends of the ligatures long, they can be used after the division of the vein to retract this structure out of sight If present an arterial branch in lateral or anterior position now comes into view (pulsations!) and can be attended to The right artery distal to the site of origin of the right paramedian artery can sometimes be followed for a short distance intrahepatically Occasionally the branches of the dorsal fan may arise from this artery some of the arteries running laterally to the right paramedian vein belong to this group Blunt dissection with the back of the handle of the knife is recommended for the purpose of following this artery, which is carried down to the vena dextra This vein lies fairly superficially below the visceral surface of the liver

Bile ducts The bile ducts are often difficult to visualize because of their ventral position Usually however a distinct right and left hepatic duct can be recognized at the porta hepatis before their junction with the common hepatic ducts The rule, mentioned previously as valid for the left hepatic arterial branches which can be applied for identification purposes during a hilum dissection also holds true for the bile ducts forming the left hepatic ducts The ducts coming from the left lobe caudate lobe and caudal area of the left paramedian lobe can be identified in the same way as the corresponding arteries and veins Even in those instances where the ducts cannot be visualized properly in the umbilical fossa on account of their ventral position to the veins one or two suture ligatures applied with a wide margin round the junctions of these three structures will equally take care of the duct

It will thus be evident that, whereas the arteries and veins

are seldom overlooked during a hilar dissection, the bile ducts frequently are. We therefore do not resect the gall bladder until the end of the operation and utilize it (by pinching) for visualizing the bile ducts. In extensive hilar dissections it may moreover be advisable to dissect out the common bile ducts for a short distance and to apply a rubber covered clamp, so that no bile can escape into the duodenum. This clamp should in no way interfere with the blood flow in portal vein and proper hepatic artery.

The right paramedian duct always courses along the medial surface of the corresponding vein, though occasionally areas of the dorsal fan may drain into the right duct by way of small ductuli lateral or anterior to the right paramedian vein. The bile duct from the right lobe runs underneath the base of the right paramedian vein.

In our opinion there are two strong arguments to be advanced against an extensive dissection at the hilum. One is that the variability of the Glissonian structures may be such as to require a very extensive hilar dissection to render the pattern intelligible. Let us recall a single instance to exemplify this. As previously stated in 18% of the specimens the left paramedian artery arose from the right hepatic artery. In this instance the arterial blood supply to the left paramedian lobe will be blocked if the right hepatic artery is ligated proximal to its origin, e.g., in a right hemihepatectomy. This, however, will mean risk of necrosis of a lobe after removal of half of the liver which should certainly be prevented if possible. As similar morphological variations were found in the bile ducts the same applies to these structures with this difference that instead of necrosis, atrophy results from blocking of the bile ducts (see p. 200).

The second argument is that only that lymphatic and nerve tissue which belongs to the part to be resected should be destroyed. Although we have studied neither of these structures, we feel that the destruction of these tissues, which must

inevitably result from an extensive hilar dissection, should be avoided.

Note: an extensive hilar dissection can be circumvented by making straight for the lobar Glissonian pedicle, detaching it and ligating it at the most distal possible point.

The approach to the Glissonian pedicles in the left half of the hilum is comparatively simple (see p. 176), except to the pedicle of the cranial area of the left paramedian lobe which is only accessible frontally, via the left interlobar fissure.

Dissection calls for more patience in the right half of the hilum. The right paramedian vein has to be released from the capsule as distally as is feasible. We explained in Chapter IV that in some cases the segments of the right lobe are supplied arterially from the right paramedian artery or drain bile into the right paramedian duct. These arteries to and the bile ducts of the right lobe arise from the artery or enter into the duct at the base of the right paramedian vein. It is for this reason as well as in view of the presence of the right artery and right duct that dissection *in situ*, *i.e.* at the origin of the right paramedian vein is preferably avoided and the utmost distal location for manipulation is recommended.

The same applies to the pedicle of the right lobe. Again the farthest distal point is advised for dissection for which the hilum may be elongated if necessary. For we have seen that in a number of cases arteries supplying areas of the right paramedian lobe or bile ducts from this area issue from the right artery or discharge into the right duct. The farthest distal intrahepatic ligation of the pedicle of the right lobe will prevent occlusion of these arteries and bile ducts.

We see, then, that usually it is not imperative to open the liver to gain access to the Glissonian pedicles but that as in pulmonary surgery, the hilum can be attended to before proceeding to resect. In the last resort, Couinaud's recent method may provide a solution but only if it is quite impossible to reach the structures from the hilum.

There is one exception, that of the pedicle of the cranial area of the left paramedian lobe Cleavage of the liver along the left *interlobar fissure is always necessary before this can* be approached anteriorly

Having, on p 165, explained how to identify the left interlobar fissure, there now remains the right interlobar fissure to be discussed It is a fissure of the very first importance to middle lobectomy

It is an observed fact that the middle hepatic vein drains nearly all the blood from the two paramedian lobes Hence, when this vein has been ligated, congestion is bound to occur in the area of the middle lobe If ligatures have been applied around the lobar Glissonian pedicles beforehand, they can be ligated as soon as congestion is exacerbated The plane along which the right paramedian lobe is brought into relief by the *congestion against the right lobe is situated slightly to the left* of the right interlobar fissure, as the right hepatic vein continues to drain blood from the area of the dorsal fin of the *middle lobe (fig 87, p 104)* By keeping somewhat to the right of the line of congestion, interference by passive bleeding, which may obscure the area of operation, can be avoided

We refer to Chapter X for a more detailed description of the possible operative procedures which emerge from the foregoing

Chapter IX

SURGICAL APPROACH TO THE LIVER

Before proceeding to discuss a number of resections we would do well to consider whether any useful suggestions can be made regarding *incision* For, the present diagnostic resources at our disposal seldom provide us pre operatively with those particulars of a surgical disease of the liver such as localization dissemination and other factors which determine, not only its operability, but also the mode and path of approach to the process This uncertainty makes it difficult to draw up a surgical plan of campaign, which has to depend upon what the surgeon finds during an *exploratory laparotomy*

Generally speaking an incision should meet the requirement both of providing adequate exposure with minimum retraction and of permitting an alteration at will if dictated by unexpected circumstances The latter, above all is very important and we must dwell upon it before we discuss the various incisions commonly employed for exploration of the right upper abdomen

With possible resection in mind we sometimes try to approach an area in which with the abdominal incisions commonly used for exploration adequate working space cannot be obtained or only with the utmost difficulty For resection of the right half of the liver, for instance such space is required in the right subdiaphragmatic area and the right flank a difficult space to approach particularly in the asthenic pa

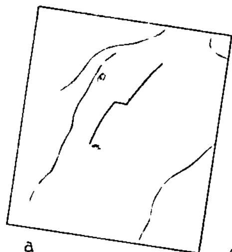
tient with his narrow costal arch, being, as it is encapsulated within the dome of the diaphragm on the cranial and caudal parts of the thoracic cage on the ventral, lateral and dorsal sides That is why in many cases the incision used for exploration has to be enlarged

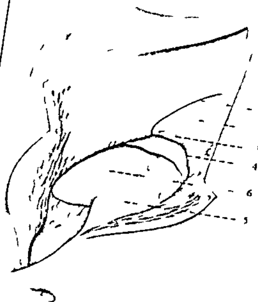
If we ask ourselves what different types of incision are generally used for exploration of the right upper abdomen, we find from an enquiry by Summers (1952) that 38 5% of surgeons use a right subcostal type of incision, 16 3% a transverse incision and 13 4% alternatively a right rectus (in the asthenic type of patient) or a transverse one (in patients of the pyknic habitus)

Every incision mentioned by Summers, except the transversal, can be used as it is, or slightly lengthened, for the *resection of the left lobe* of the liver (see fig 111) As we ascertained in cadaver experiments, it is not even necessary to use the ⊥-shaped incision recommended by Raven (1949) for this resection, nor yet the ⌋-shaped incision of Anschutz (1903) The incisions enumerated by Summers are less effective for *left hemi hepatectomy*

If difficulty is encountered in dissecting at the hilum or, as in the case of an asthenic patient, the cranial surface of the liver and the vena cava inferior are difficult to approach extension of the incision by sternum splitting (see fig 109) will be found of considerable assistance, as they were in our cadaver experiments The skin incision is extended upwards along the axis of the sternum as far as about its centre The xiphoid process is resected, following which the sternum is split obliquely from the base to at least one third of its length (Wahren

Fig 109 Extension of right paramedian incision by means of the sternum splitting incision
A Ventral aspect B Xyphoid process removed diaphragm detached from sternum 1 Line of incision at sternum 2 Sternum 3 Surface along which xyphoid process was resected 4 Diaphragm detached from sternum 5 Falciform ligament 6 Pars dextra hepatis C Left side view 7 Vena cava inferior





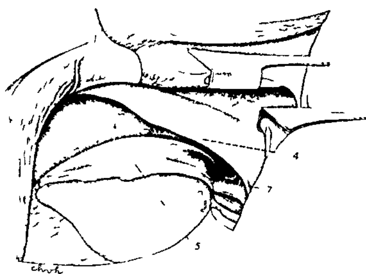


Fig 109

et al, 1954) Care should be taken to avoid opening the pleural cavity (pneumothorax) or pericardium, which are both freed bluntly from the sternum by finger dissection before the sternum is split The splitting may be carried out by means of a pair of rib scissors It is possible to enlarge the working space even more by dividing the diaphragm in a downward direction to the inferior vena cava

This, however, is of no avail for operations on the *right half* of the liver The problems then raised are far more intricate than those facing the surgeon who finds by exploration that a radical gastrectomy is indicated, for which Garlock (1946), Humphreys (1946), Carter (1947) and others recommend the combined abdomino thoracic approach It is for this reason that Lortat Jacob and Robert (1952) solved the problem of the approach to the right half of the liver in a similar fashion, *viz*, by extending the exploratory abdominal incision into the thoracic cavity

This incision was developed by Rio Branco (1912) There are several modifications of this method, mainly for portocaval shunt surgery (Carter, Heaney & Humphreys, Lortat Jacob) A right rectus or right paramedian incision is used to explore the abdomen, the incision being extended upwards as far as the costal margin When incision is to be extended into the thorax, a sandbag is placed under the patient s right side in the renal region If resection is decided upon, a long curved incision, starting from the former one, is made over the 8th intercostal space up to the mid axillary line to the right and across the costal margin to the left The incision is continued downwards into the chest (fig 110 A)

The common costal cartilage is divided between the 8th and 9th ribs A radial incision, extending from its origin at the point of division of the costal margin to the inferior vena cava divides the diaphragm A Finochietto retractor is placed between the divided ribs and spread out The falciform ligament is divided Right lung, stomach and intestines are packed

with moist pads, the former in an upward direction the latter downwards and sidewards.

This procedure facilitates both mobilization of the right half and the approach to the two hepatic gateways with plenty of room. Experience gained in experimental surgery has, moreover, shown that, anatomically too it is quite the best way for mobilising the liver from all sides. Whether from the physiological point of view it is likewise the best approach to the organ is a debatable point. There are some who feel that entering the abdomen by way of the thorax is undesirable and only a makeshift solution of the problem (Wahren & Vikgren 1954).

We know of no incision meeting all the requirements other than by way of the thorax. We have tried out all existing incisions and their various modifications upon cadavers one of which only we should like to describe in more detail. By cutting the costal arch (Clute and Albright 1938), more working space can be obtained in the right upper abdomen. This is a principle applied by Holman (1950) in a subcostal incision parallel to the costal arch which he advocated for porto-caval shunt surgery.

The procedure is to explore through a subcostal incision which is made a few centimetres below and parallel to the midcostal margin. If resection is decided upon the incision is extended in a latero-caudal direction up to a point situated in the anterior axillary line at the same level as the umbilicus and medio-cranially towards the xiphoid process. The lateral skin flap and the subcutaneous tissues are displaced laterally from the costal margin by dissection and a subperichondral resection of a small piece of cartilage of the costal margin is carried out at the level of the 5th intercostal space.

In the broad-chested type the right half of the liver can be approached by the lateral displacement of the costal margin. Excellent exposure of the hilum is obtained by means of this incision.

In cadavers however we found that this incision, without opening the thorax, is only satisfactory for the broad-chested hypersthenic type of patient.

Chapter X

ON HEMI-HEPATECTOMY AND SOME HEPATO-LOBECTOMIES

Possible operative procedures which emerge from the foregoing may be detailed as follows

A Hemi hepatectomies

This technique is based on the fact that the liver is a paired organ as regards its Glissonian system

The plane of division of right and left portal vein trunks, hepatic arteries and hepatic ducts and their ramifications the fissura media, divides the gall bladder bed of the liver into two and is directed cranially to the left side of the inferior vena cava This plane corresponds to the plane of resection in a hemi hepatectomy even though the liver is not a paired organ as regards its second intrahepatic system, *i.e.*, the hepatic veins *As described previously, this system consists of two* groups of veins namely (1) the venae hepaticae breves coming from the left and right dorsal surface of the liver and each ending individually on either side of the inferior vena cava, and (2) the major hepatic veins leaving the liver at the most cranially and centrally situated area both on the right and the left side carrying the blood from the liver into the inferior vena cava just below the diaphragm One of the hepatic veins the vena hepatica media, runs in the fissura media, it usually carries blood from the lobes situated on either side of the fissure to the left hepatic vein The junction of both veins is

situated only slightly to the left of the left side of the inferior vena cava

If resection of the *right half* of the liver is carried out, the liver is gently retracted downwards, stretching the triangular ligament (see fig 110 B) This ligament consists of two leaves, an anterior ligamentum hepato-diaphragmaticum and a posterior one, the ligamentum hepato renale Between these two leaves the cranial pole of the liver is bare and very friable The anterior leaf is first divided the dome of the liver being followed and care taken to avoid injury to the diaphragm To free the liver further, the hepato-renal ligament at the dorsal right side has to be severed The right half of the liver is therefore gently rotated upwards the ligament being divided during the rotation, the scissors should remain close against the liver to avoid damage to the right adrenal gland (fig 112)

The right part of the liver is thus completely free from its surroundings and is freely movable for a considerable distance in almost all directions When the right lobe is rotated to the left, the inferior vena cava is stretched and can be identified by its peritoneal covering While this vessel is dissected out the venae hepaticae breves on the right become visible (fig 110 C) These veins are attended to after ligation of the hilar structures

This is when hilar dissection may begin The liver is rotated upwards through the diaphragmatic defect into the right lower thoracic cavity during which manoeuvre the hilar region is exposed When removing the liver from its bed, care should be taken not to overstretch the hilar structures (fig 113)

For resection of the *left half of the liver* through an abdominal incision the left liver lobe should be turned laterally and the hilum approached from the left instead of from the right Hence the surgeon stands at the left side of the patient (fig 111)

At the hilum the structures are ligated where the trans verse fossa merges into the umbilical fossa for a left hemi hepatectomy, and at the right hilar margin for a right hemi hepatectomy

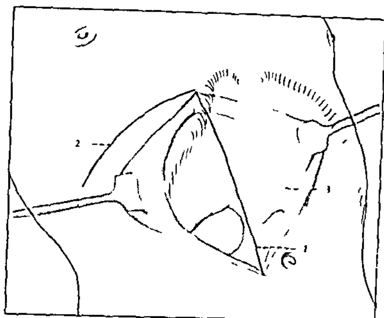
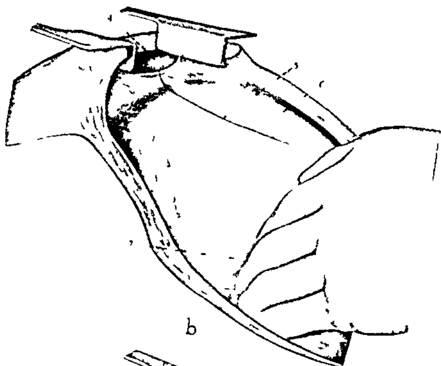
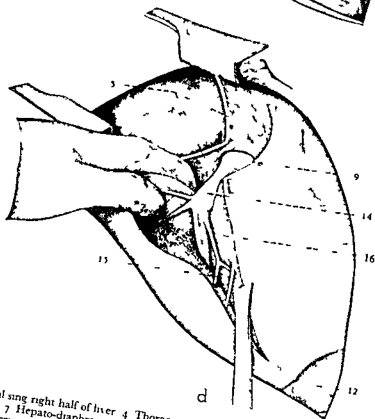


Fig 110 Right hemihepatectomy seen from the right
A Skin incisions with exploration of abdominal cavity 1 *Abdominal incision* (right paramedian or right rectus incision) 2 Intercostal incision 3 Falciform ligament *B Abdomen and thorax opened* 4 *Thoracic cavity* 5 Line of incision of diaphragm C Diaphragmatic arch Hepatodiaphragmatic ligament stretched as result of pulling down right half of the liver





ıbil sıng rıght half of lıver 4 Thoracıc cavıty 5 Lınes of ıncısıon of d a
n 7 Hepato-dıaphragmatıc lıgament 8 Hepato renal l gament 9 Vena
ıferıor 10 Short hepatıc veıns 11 Bare lıver area 12 Gall bladde
ht adrenal D Separatıng the lıver along the fıssura medıa 5 Lınes of
of d aphragm 9 Vena cava ınferıor 12 Gall bladder 14 Vena hepatıca
medıa 15 Venulae hepatıcae 16 Fıssu a med a.

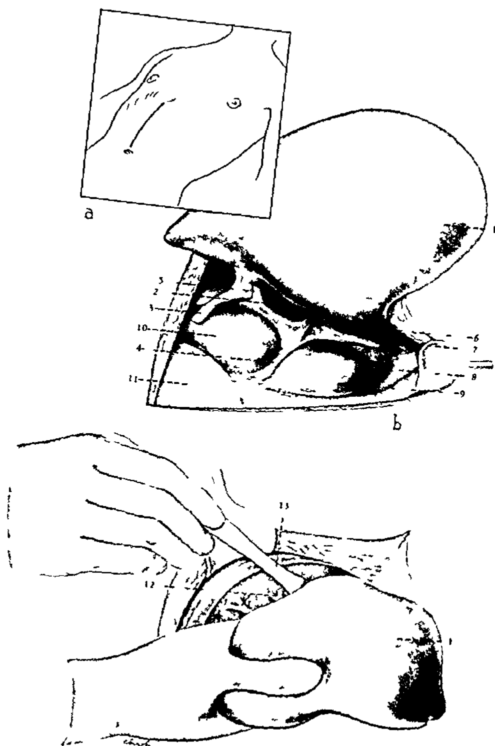


Fig 111

After ligation of the Glissonian structures at the hilum of the liver, the latter will, theoretically, shrink and turn pale on account of the depletion of blood on one side This however is frequently not the case, as we observed in dogs and as was noted during a hemi hepatectomy Nor did Bax see any decoloration in his case

Before the liver is divided the plane of resection is marked by a sharp division of the liver capsule Then blunt division of the liver is advisable, as performed by us first in dogs and later in a patient, its advantage is that the hepatic venule crossing the plane of resection are not opened, on the contrary, they can be dissected out ligated and divided (fig 110 D)

Both to prevent haemorrhages and injury to the medial hepatic vein we advised resection of the liver along a plane parallel to and only *slightly* to the left (in a left hemi hepatectomy) or to the right (in a right hemi hepatectomy) of the fissura media so as to devitalize as little tissue as possible (Gans, 1954)

The raw liver surface is then re peritonealized (omentum falciform ligament gall bladder, etc)

B Hepato lobectomies

Left hepato lobectomy The umbilical fossa is dissected out and the two (occasionally three) segmental branches of the left lobe are identified the cranial vein the intermedial vein and the caudal vein of the left lobe, the first at the convexity of the left portal vein the latter at the saccus (fig 111) In all our specimens the Glissonian structures joined at these points to

Fig 111 Left hepato lobectomy
A Midline incision B Left lobe turned upwards lesser omentum removed Left side view
1 Left lobe 2 Line of incision along lesser omentum 3 Ligamentum teres hepatis 4 Transverse segment of left stem of the portal vein 5 Vena caudalis lobi sinistri 6 Vena cranialis lobi sinistri 7 Left hepatic vein 8 Vena cava inferior 9 Caudate lobe 10 Quadrate lobe 11 Colon
C Resection of left lobe Left side view
1 Left lobe 12 Hepatic venules 13 Back of the handle of the knife



Fig. 112. Division of the ligamentum hepato-renale seen from dextro-caudally.
1 liver 2 bare liver area 3 ligamentum hepato-renale

continue their intrahepatic course into the left liver lobe together Adequate care can be taken of all Glissonian structures of the left liver lobe by wide use of transfixion sutures at the sites mentioned above, namely around these two or three structures The dorsal surface of the liver faces the surgeon during this procedure The liver is brought back into its normal position and held by the assistent The left hepatic vein is ligated at the cranial liverpole The capsule is incised sharply along the left interlobar fissure as indicated previously after which the liver is divided bluntly along the fissure, again without opening the hepatic venules before they are ligated individually The raw liver surface is then re peritonealized (omentum falciform ligament, etc)

Occasionally a bar of liver tissue bridges the space between the left caudal segment and the quadrate lobe overlying the saccus in the caudal part of the umbilical fossa This bridge of tissue is usually quite thin but is must be divided in order to permit of an adequate approach to the saccus

In a left lobectomy this bar is divided bluntly along the dorso-medial margin of the left liver lobe in a resection of the middle lobe in which the left lobe is left behind it is divided near the margin of the quadrate lobe

In cancer of the gall bladder the first parts of the liver to be affected are the adjoining liver lobes This area shows numerous anastomoses between the blood and lymph vessel systems of both organs, which may be considered the pathways along which the spread of the tumour growth into the liver took place As will be pointed out a resection of the pars dextra enables us to remove all diseased parts of the liver in early carcinoma of the gall bladder

We developed a *middle hepato lobectomy* on a theoretical experimental basis an operation which seems to be suitable for resection *in toto* of the medial lobe of the liver together with the gall bladder

As some of the principle of this operation have been developed in the previous chapters (p 170 and 182) we shall now only briefly consider the operative procedure itself



Fig. 113. Right hilum of the liver after removal of the capsule in the right incisura. 1. Ligature around the right portal vein. 2. ligature around artery and bile duct which cross the base of the right paramedian vein.

First of all the Glissonian pedicles of the right paramedian lobe and the paracystic area of the left paramedian lobe are exposed after which ligatures are applied around these structures but are not tied.

The middle hepatic vein is dissected out at the cranial pole of the liver and ligated, which is followed by engorgement of the middle lobe; as soon as the area of the right interlobar fissure is clearly demarcated, the Glissonian pedicles are ligated. The liver is opened bluntly along the right interlobar fissure which runs slightly to the right of the line of demarcation; minor branches running from the right paramedian lobe to the right hepatic vein are ligated individually.

The left interlobar fissure and the dorsal fissure are opened in the same way in a downward direction as far as the sagittal part of the left portal vein. At this moment the Glissonian pedicle of the ventrocranial part of the left paramedian lobe is attended to. It is dissected out at the ventral aspect of the sagittal part, ligated and divided. Thus the whole medial area is freed from the surrounding parts and can be taken out after Glisson's capsule and the containing structures have been dissected out of the transverse fossa.

Care should be taken to avoid damage to the right and left hepatic veins and the hilar structures, both during dissection and removal of the resected tissue.

Still being in doubt as to the practical efficacy of a right hepato lobectomy, which, moreover, seems to us a very tricky operation to perform, we shall for the present leave it out of discussion.

Resection of the pars dextra hepatis, in which the left lobe and the caudate lobe are left behind, can only be performed if sufficient liver tissue is left to support life. The left lobe may occasionally be completely absent (Hammer 1928, Benz 1952).

In this operation the right hepatic artery, right hepatic duct

and right portal vein are identified and ligated near the right hilar margin In the umbilical fossa the capsule is incised along the quadrate lobe, the Glissonian pedicle of the caudal area of the left paramedian lobe is dissected out and widely ligated The right and medial hepatic veins are dissected out and *ligated at the cranial pole of the liver The liver is opened* along the left interlobar and dorsal fissure in a downward direction as far as the sagittal part of the left portal vein At this moment the Glissonian pedicle of the ventro cranial part of the left paramedian lobe is attended to It is dissected out at the ventral aspect of the sagittal part, ligated and divided

The pars dextra is now rotated so that the hilum can be approached from the front and its structures dissected out of the transverse fossa The Glissonian pedicle to the right liver half is ligated and divided after which the whole pars dextra is freed from the surrounding parts and can be taken out

The raw liver surface is then re-peritonealized

Chapter XI

THE CARE OF THE PATIENT BEFORE, DURING AND AFTER HEPATIC SURGERY

The fundamental principle upon which hepatic surgery was at one time thought to be based is the organ s tremendous regenerative capacity an attribute which even the ancients probably recognised as witness the Greek myth of Prometheus It will be remembered that as a punishment imposed upon him by the gods part of his liver was picked out every day by a bird of prey and according to the story was able to survive for centuries because the liver restored itself completely over night

Since Gluck (1884) and Ponfick (1889) resected large parts of the liver in animals, it became common knowledge that up to 80% of the organ can be removed without ill effects to the organism while the remnant regenerates to such an extent that the organ regains its pre operative weight within a relatively short period of time

This regeneration however is subsequent to resection Yet the patient lives on and as a rule the residue of the liver continues to function normally

Indeed as Schalm and co workers (1951–1954) have pointed out the fact that a patient is able to tolerate so extensive a resection is not due primarily to the regenerative power of the liver but to its functional reserve capacity which enables the organism to function normally on 20% (or more) of the normal liver tissue They ascertained that when a large part

of the organ is 'functionally' lost, the various function tests however subtle, rarely show any alterations, provided the liver was normal to start with

Regeneration only takes place secondarily! Hence it is of the utmost importance that the organ should be functionally in the optimum condition when part of it is to be resected, because the 'reserve capacity' of the organ will decrease as its condition deteriorates In other words, the function of a normal liver can be carried on by a remainder representing at least 20% of the normal weight of the organ However, an extensive resection of this kind performed upon a liver in a worse condition may result in failing compensation of its functional capacity which is clinically manifested as 'hepatic failure'

Schalm and co workers explain along these lines why the function tests made upon a liver affected by localised pathology—as contrasted with livers affected by generalised hepato cellular disease—are usually normal

Acceptance of this conception implies, if surgery is decided upon, that it becomes a duty to make every effort to increase the functional reserve capacity of the organ so as to avoid the risk of a post operative hepatic failure, for which we hope to provide a number of rules in this chapter

As has been stated, Ponfick was able to remove two thirds to four fifths of the liver, following which the animal recovered while developing hypertrophy of the spared part New liver tissue was observed within about five days, and the average pre operative weight was recovered after six weeks or thereabouts (dogs) in patients this period was within 70 days (Loealio & Satz 1950)

The regenerative capacity of the liver is reduced if the free drainage of bile and the portal blood supply are hampered Nasse (1894) and later Mann *et al* (1920–29), and Schalm *et al*, demonstrated that blocking of bile ducts results in atrophy of the parts of the liver deprived of their ability to give off bile via these ducts This atrophy however will be com

pensated by the hypertrophy of the other parts of the liver left with free biliary outflow Similar results were obtained after occlusion of one of the branches of the portal vein (Mann *et al*, Schalm *et al*)

Livers of young rats regenerate more rapidly than those in old rats (Buchner *et al* 1947)

A group of rats was put on a low protein diet for some time and then subjected to a 70% hepatectomy this led to the death of most animals (Gurd & Vars 1949)

Mann *et al* who made a thorough study of the problem of regeneration, pointed out that restrictions of the restorative power of the liver are largely dependent upon a decreased portal blood flow and injuries to the liver such as cirrhosis restricting the portal blood flow will further aid in this characteristic

The regenerative process is favoured by high carbohydrate diets (Davis & Whipple 1921) high protein diets (Gurd & Vars 1948 Vars & Gurd 1947) diets rich in vitamins (Denton & Ivy 1948), and by some hormones such as adrenal cortical extracts thyroid hormone in moderate doses and testosterone Occlusion of the arterial blood supply does not seem to exert any adverse influence on the regenerative processes in the rat (Wiles *et al* 1952)

It is not as imperative as in the case of the lungs where every type of resection is attended by a loss of function to choose the smallest possible hepatic territories for resection (*i e* segmentectomies), thanks to the great functional reserve capacity of the organ and its regenerative power At present therefore we are not in favour of segmental resections for the following reasons

(1) The morbid conditions in the liver are only rarely limited to one segment, generally extending across the segmental borders into the adjacent segments

(2) Segmental resections are technically much more difficult to perform (and therefore are more hazardous to the

patient) than somewhat more extensive resections, which were discussed previously

A SOME REMARKS ON THE PREPARATION OF THE PATIENT BEFORE SURGERY

It is imperative to obtain some insight into the pre operative state of the organ The first step is to enquire into the dietary history of the patient It is highly important to record not only the quantity, but also the quality of the foodstuffs usually constituting the patient s diet The daily consumption of meat (*especially as regards fat meat and gravy*), *fish and fowl*, *fruit* and vegetables, dairy products, condiments and spices (pepper, paprika, sambal, vinegar, curries, mustard, etc) should be known These data can be obtained from the patient or his family Tactful questioning may reveal the patient s habits with respect to alcoholic beverages, a knowledge of kind and amount of the daily alcohol is also required

Anorexia and loss of weight may be indicative of protein deficiency, this may be especially the case if there is a concomitant hypoproteinaemia

Our decision whether operation should be performed at once or postponed until corrective measures have taken their effect, *is partly based on the knowledge gained from the patient or* his family Optimal nutritional conditions are imperative, as they constitute the most important prophylactic factor, helping in protecting the liver against damage by various noxious substances and in promoting the regeneration of hepatic tissue

The liver is highly susceptible to dietary deficiency, frequently caused by dietary imbalance, the resulting changes in the liver cells may be indistinguishable from those caused by toxic agents or anoxia These deficiency conditions should therefore be corrected *by diets rich in carbohydrates, proteins* and vitamins A few hints may aptly be given here regarding the daily consumption of these foodstuffs

Carbohydrates Glycogen besides exerting a protecting effect on the liver cells also may act as a protein sparing agent On feeding 100 grams of protein 58 % of these proteins ingested are spared conversion to carbohydrates if the carbohydrate intake is adequate (Bollman 1941)

Woodyatt *et al* (1915) found that 60 g of intravenously administered glucose per hour could be utilized by a normal man without the development of glucosuria This is 45 g higher than the basic metabolic requirements which are mainly stored in the liver in the form of glycogen Opie & Alford (1914) proved in animal experiments that though the liver is able to accumulate considerable amounts of glycogen in normal cases in the event of liver damage higher blood glucose concentrations are required before glycogen can be stored In the latter case intravenous administration is necessary to supplement the oral intake This method of administration is also preferred in case of vomiting or when early surgery is indicated and there is only a short time available for proper preparation

The amounts of carbohydrates given daily should vary between 300 and 500 g (Morrison 1947) Foods rich in carbohydrates are potatoes fruits vegetables sweetened fruit juices cereals honey candy jam etc If the intravenous route is chosen for the reasons mentioned above invert sugar (composed of equal parts of dextrose (D glucose) and laevulose (D fructose)) is better than dextrose

Proteins Daily amounts of at least 100 g protein have been advised some authors go even as far as recommending daily intakes exceeding 200 g (Morrison)

The importance of this dietary component in the conditioning of the liver against injury caused by noxious agents has been emphasized by various investigators (Radvin *et al* 1929 Himsworth & Glynn 1944 Smith *et al* 1928 etc)

The process of detoxication is only partially understood it may take place by conjugation of exogenous poisons and amino-acids by the absorption of toxic substances by plasma proteins (bile salts) through immunity or resistance to infections (globulin fractions) or by enzymatic processes in which proteins are required for the formation of the enzymes Mobilization of fat from the liver cells decreases the susceptibility of these cells to injuries certain amino-acids the so called lipotropic agents acting as methyl donors in the process of transformation of fat into plasma phospholipids are indispensable (choline methionine)

The liver is able to cope with excessive amounts of proteins (Dock 1947) Milk cheese lean meat chickens and eggs are foods rich in proteins milk in particular is to be recommended (Schalm 1951)

In view of the fact that one litre of whole blood contains only about 150 grams of protein it will be evident that the amount which can be administered in this way is insufficient to correct a severe state of hypoproteinaemia

Oral intake or tube feedings are therefore imperative but additional intravenous administration of whole blood is indicated in cases of anaemia and hypoproteinaemia because these patients are more susceptible to

post operative haemorrhagic or traumatic shock (Ravdin *et al* 1951)

The most important factor to be borne in mind in the composition of a *diet is its palatability* It is therefore impossible to eliminate all fats (Hoagland 1945) Small amounts of fat not only improve the savoriness of the diet but moreover promote the utilization of carbohydrates as well as of proteins (Elvehjem *et al* 1947)

Feeding by stomach tube is occasionally necessary for those patients who are unable to eat or who are unwilling to take up sufficient quantities The food mixtures used should always be prepared freshly in order to prevent contamination

Vitamins are as essential in the diet as proteins both are needed for the production of enzymes

The daily thiamin requirement—necessary for lactic acid metabolism—is 10–20 mg by mouth or intravenously and of niacinamide 50 100 mg Nicotinamide deficiency may lead to hepatic insufficiency with concomitant porphyrinuria (Rafsky & Newman 1943) Folic acid seems to possess a lipotropic effect vitamin C promotes the utilization and storage of carbohydrates in the liver and participates in the intermediary metabolism of some amino acids (tyrosine) It decreases the deposition of fat in the liver and protects it against damage Liver extract is a powerful protective substance and promotes the regeneration of this organ (Forbes 1939)

The relationship between prothrombin concentration of the blood and vitamin K is well known

A number of medical conditions influence the operative risk *e g*, endocrine disturbances such as diabetes hyperthyroidism moreover cardiac hepatic and renal affections

Generally speaking, evaluation of the patient and his cardiac hepatic and renal reserves, and correction of the functional disturbances of these organs as far as possible, are necessary if the body is to be able to cope with the strain imposed by hepatic surgery Examination of the patient by a specialist of internal diseases is therefore a wise policy[1]

B DANGERS AND SAFEGUARDS DURING SURGERY

During surgery a number of problems arise such as prevention of air embolism the choice of the anaesthetic, the reaction of the organ to manipulation at one of its gateways etc which will be discussed here briefly

In 1911 Fiegel instituted an investigation into *air embolism*

after observation of a case in which this complication arose due to the accidental opening of a large vein in the intraclavicular area. The negative intrathoracic pressure proved to be transmitted to the venous system in the immediate neighbourhood of the chest, as appeared from his experiments. Upon opening the thoracic cavity, the negative pressure falls immediately, which reduces the chance of air embolism. On intubating the patient controlled respiration can be applied. The latter can easily be used for re-breathing under positive pressure which, in Tiegel's experiments, led to a rise of the intracranial pressure. In this way air embolism can be prevented.

To determine the pressure in the hepatic veins, pressure readings were taken in these veins with closed thoracic cavity during cardiac catheterization (De Vos 1954). The average pressures varied between zero and + 1 cm H_2O, being negative during inspiration and positive during expiration.

During a hemi-hepatectomy performed with closed chest, opening of the hepatic veins resulted in slight bleeding during expiration which stopped completely during inspiration; a withdrawal of blood was actually observed during the latter phase. The negative intrathoracic pressure during inspiration is transmitted to the hepatic vein system. Prevention of air embolism by re-breathing under positive pressure has the disadvantage of increased venous bleeding due to a rise in venous pressure. We therefore no longer sever the hepatic venules before they are ligated. This can only be done by dividing the liver bluntly, which we first attempted in dogs with satisfactory results. Furthermore it is advisable to intubate patients who are undergoing liver operations.

Anaesthesia produces a considerable hyperglycaemia (Tannhauser 1916); there is evidence that this is due to hepatic glycogenolysis (Mekie 1931). The parenteral administration of glucose not only during the pre- and post-operative periods but also during the operation has been emphasized by Pareira

& Probstein (1949), who studied the degree of assimilation of infused glucose The maximum hyperglycaemia occurs immediately after the operation, followed by a fall towards the preoperative blood sugar level, which is usually reached within about eight hours There is a close relationship between the absolute rise of the blood sugar level and the duration of anaesthesia In cases of post operative shock the blood sugar level is also high

Moreover, the liver plays an important part in the inactivation or detoxification of numerous substances It is therefore not surprising that the duration of the activity of thiopental (pentothal) is considerably prolonged in patients with liver affections (Shideman *et al*, 1949) Cats, partially hepatectomized after anaesthesia with certain drugs (chloral hydrate, brometol, thiopentone and soluble phenobarbitone), remained *unconscious* for a longer time than normal animals (Walker & Wynn Parry 1949), which shows that these substances are detoxified to some extent in the liver This fact ought to be taken into account while planning an extensive resection

Some anaesthetics exert an adverse influence on the function of the liver Bourne *et al* (1930), for example, observed impaired liver function for a period of eight days, caused by 30 minutes chloroform anaesthesia Two hours anaesthesia with this drug led to alterations in the hepatic function for six weeks Chloroform is therefore the most notorious hepatotoxic anaesthetic agent

Ether anaesthesia causes only a slight depression of the liver function, 15% dye retention is found after 24 hours in the B S P test, but the values returned to normal after 48 hours

Bourne (1939) demonstrated that nitrous oxide or ethylene anaesthesia of 1–2 hours duration did not cause immediate or remote impairment of the hepatic function if sufficient oxygen was administered at the same time, of all animals the function was affected however, if the percentage of oxygen administered was deliberately reduced The values did not return to

normal in as short a time as in ether anaesthesia about six days being required for recovery

Cyclopropane has absolutely no adverse influence on the liver function, as shown by Raginsky & Bourne and is therefore the anaesthetic *par excellence* being not only perfectly suitable for patients with hepato cellular diseases but also in cases of hepatic surgery

The condition of the liver is the determinative factor for the response to the anaesthetic agents the adequacy or inadequacy of the patient s diet before the anaesthesia is another important factor in this respect

The prevention of anoxia during surgery is a pre requisite (Mekie 1931)

The trauma caused by the manipulations during surgery results in a *depression of the hepatic function* Lord (1939) noticed a fall in the plasma prothrombin concentration after surgical exploration of the liver

A negative nitrogen balance is usually observed after any major operation A significant fall of the serum albumin level may also occur frequently persisting for some time after the operation it should be corrected by oral or tube feeding with additional transfusion of whole blood human plasma or if necessary human serum albumin General and local trauma together cause a stress situation leading to impairment of the liver function the degree of the damage depends on the pre operative condition of the organ and the strain imposed on the individual Depletion of the carbohydrate and protein reserves makes the liver extremely susceptible

Manipulation on retraction or compression of the vascular pedicle entering the liver may result in massive or confluent centrilobar necrosis due to impediment of the hepatic blood flow and anoxia of the liver in addition to the strains mentioned before

Burton Opitz (1911) found the following figures in animal experiments about 40% of the oxygen required is transported by the hepatic arterial blood, which constitutes only about 25% of the total amount of blood reaching the liver The portal vein carries about 75% of the total amount of blood, contributing with 60% to the total oxygen saturation

The previous paragraph shows that the *hepatic artery*, although carrying only a minor part of the total hepatic blood supply, is of very great importance as regards the oxygenation of the liver A great many publications on the results of occlusion of this artery have been published since Malpighi's observations in 1699, who noted in animals that ligation did not interfere with the secretion of bile

As pointed out by Von Haberer (1905), proximal ligation of the vessel is readily compensated by numerous collaterals

We have already discussed that, under normal conditions most of the branches of the hepatic artery at the hilum are end arteries in the sense of Cohnheim Interruption of the proper hepatic artery distal to anastomoses with other vessels (gastroduodenal artery, right gastric artery, etc) or at the hilum of one of its branches may lead to changes varying from very mild ones to extensive necrosis of the areas deprived of their arterial blood supply, the latter condition is usually associated with necrotic changes in the wall of the gall bladder

Dogs always died after ligation of the hepatic artery, if the site of ligation was distal to the anastomoses mentioned (Von Haberer 1905) Narath (1915) was able to prevent death by anastomosing the hepatic artery with the portal vein Liver protecting agents were entirely unable to change the course of events (Barattı *et al* 1952), which means that the acute hepatic necrosis, with or without rupture of the gall bladder that followed the ligation was apparently of a toxaemic rather than of a simple nutritional nature

In 1909 Wolbach & Saiki demonstrated the presence of spore bearing anaerobic micro organisms in healthy dogs

this finding was confirmed by Markowitz in 1949 and by many others subsequently This fact explains the septic clinical manifestations under which these dogs when deprived of their arterial blood supply, died within a period varying from 15–60 hours

The picture was completely changed however by the use of antibiotics especially penicillin and aureomycin (Markowitz) Untreated dogs show a fatal septic necrosis of both liver and gall bladder, the portal vein branches being filled with masses of bacteria (Hartroft 1947) Of the dogs treated with antibiotics about two thirds of the survivors showed a diminished hepatic function during the first few days, but the hepatic insufficiency had disappeared by the 12th day after operation (Fraser *et al* 1951) This leads to the assumption that the antibiotics prevent the anaerobic micro organisms normally present in the dog s liver from growing and releasing their toxic products on the susceptible liver cells during the period of hypoxia between the moment of hepatic artery ligation (Markowitz 1949) and the time when the collateral circulation is probably able to take over (Von Haberer 1905 Segall 1923)

Though Romieu & Brunschwig (1951) were unable to demonstrate similar micro organisms in the liver of healthy human beings Lowe *et al* (1951) found that several livers of patients who died after hepatic arterial ligation contained gas probably originating from a fulminating infection by anaerobic gas producing bacilli which are normally present in the intestines and probably transported to the liver via the portal vein or biliary canaliculi

Though formerly compression of both hepatic artery and portal vein was recommended during liver surgery (Baron 1910) at present it is realized that this can only be done as a last resort—and then for as short a time as possible

Sudden occlusion of the *portal vein* causes a transient shrinkage

of the liver, with return *to normal within a few minutes* with out any change in colour Compression with total occlusion of the portal vein and its results are discussed by Peck & Grover (1952) These authors observed a sharp fall of the arterial blood pressure immediately after sudden occlusion of the portal vein This fall appeared to be of a reflex nature and it was followed by a further but gradual reduction of the blood pressure, which caused death *in deep shock within an hour* This secondary fall *was apparently due to changes in the* blood volume The impression was gained from these experiments that the initial fall of the arterial blood pressure originated in the splanchnic mesentery and not in the liver A temporary suppression of this response could be effected by means of corticotrophin (ACTH), but not with cortisone The gradual secondary decrease is a result of blood pooling within the peripheral portal system

*Gradual occlusion does not elicit this response, if a sufficient*ly long period is allowed for the development of collaterals

However, in a number of cases, recently operated on (pancreatico-duodenectomy) by Child *et al* (1950), deliberate sudden occlusion of the portal vein by means of ligation was tolerated in both monkey and man The blood pressure in most instances returned to the pre operative values within 20–30 minutes

We have seen that the temporary or permanent occlusion of the portal vein and proper hepatic artery often cannot be tolerated and it remains to add that in many cases the occlu*sion* of branches of the vena hepatica system may *lead to fatal* results This depends largely on the area of the liver that is depri*ved of its means of blood drainage*

Obstruction of the *hepatic veins* (Budd Chiari Syndrome), though in general due to a primary endophlebitis from the hepatic veins or to obstruction by tumour or abscess, may be the result of a technical error during surgery Occlusion of one

or more branches may result in the acute form of the syndrome It is characterized by a sudden access of abdominal pain nausea and vomiting The liver and spleen enlarge rapidly, massive ascites appears, usually followed by death in hepatic coma within one to four weeks The diagnosis ante mortem is difficult only ten of the cases reviewed by Thompson (1947) were diagnosed ante mortem Gradual occlusion of the various trunks of the hepatic vein is accompanied by atrophy of the part which is unable to drain its blood and followed by hypertrophy of the residual normal organ (Murray & Kimmel 1949) From these facts it is clear that during surgery care should be exercised to avoid injury of the major hepatic veins marking the plane of resection

Although occlusion of smaller vessels may often not have fatal results the need for careful preparation at both gateways of the liver will be obvious from the preceding paragraphs

Upon completion of the operation we advise leaving one drain in the subdiaphragmatic area and another against the liver in the region of resection The removal of these drains is effected in the same way as in other fields of surgery

C ON SOME COMPLICATIONS IN THE POST OPERATIVE PERIOD

Many complications may occur in the post operative period namely those associated with this special type of surgery in particular and those incident upon any type of surgery, generally We shall be mainly concerned with the former, the latter can be found in any textbook on this topic Our subjects will be post operative shock portal vein obstruction cholerrhagia pulmonary complications paralytic ileus liver cell embolism infection and hepatic failure

Shock has a very adverse effect on the condition of the liver

Friedman *et al* (1951) observed radiologically a narrowed intrahepatic portal vascular bed in the dog while Seneviratne

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(1949) found a narrowing of the sinusoids during hypotensic conditions following *haemorrhage in the frog*

Wiggers (1946) found a reduction of the portal blood flow *through the liver during periods of hypotension*

It is assumed that hepatic anoxia is followed by a narrowing of the sinusoids or else by swelling of the liver cells to such an extent that the hepatic cells are no longer accessible to adequate amounts of oxygen In course of time a vicious circle develops and the changes *may become irreversible (irreversible shock)*

If the condition of shock lasts longer than 24 hours, the initial swelling of the liver cells results in a centrilobar liver cell necrosis (Ellenberger *et al*, 1951)

In Delorme s experiments (1951), in which the liver of dogs was perfused with oxygenated arterial blood while the animals were kept at a given level of hypotension, these dogs showed a marked increase in resistance to the duration of hypotension *as compared with controls, up to prolonged periods*

Narrowing of the intrahepatic portal vascular bed may moreover occur after a variety *of conditions in which the liver* cells are damaged, such as inadequate diet, incorrect anaesthesia, surgical trauma, infection, loss of blood, respiratory troubles, ileus, etc, all these conditions are commonly encountered after surgery

It is easy to see that these various factors may well tend to render a post operative shock caused by trauma, haemorrhage etc irreversible When treating for shock it is necessary, in addition to coping with the direct cause of the shock, to deal vigorously with any *damage the liver may have suffered*, using whole blood and oxygen It has been found, moreover, that antibiotics like *penicillin and aureomycin are useful aids in the* treatment of shock (Fine *et al*) It is assumed that anaerobic spore bearing micro organisms *have* an opportunity *of* proliferating during the period of hepatic hypoxia and this can be prevented by administering antibiotics

Portal vein thrombosis Of the three main types, described by De Josselin de Jong (1912) both the truncular and the terminal type may occur, the former affecting the main stem of the portal vein the latter the intrahepatic branches The number of cases reported in patients operated on by the new method of hepatic surgery is very small, but both Lortat Jacob *et al* (1952) and we instituted anti coagulant therapy Nothing definite can therefore be said of the incidence or the initial symptoms of this complication of hepatic operations Nonetheless it should be kept in mind and one should not hesitate to start anti coagulant treatment if any of the three symptoms *abdominal distension splenomegaly* and *ascites* should arise

Paralytic ileus Distension of the intestine especially of the stomach causes impairment of the liver function in rats due to the impeded hepatic blood flow this was shown by Estrada *et al* (*l c* Ravdin & Vars) Intestinal obstruction per se has been the cause of simultaneous failure of liver and kidney function resulting in some instances in acholia and anuria (hepatorenal syndrome Schnedorf & Orr 1942) It is not known whether this is due only to abdominal distension Following surgery on the liver therefore continuous Wangensteen suction is indicated in all cases

Pulmonary complications It is imperative to maintain an open airway and to prevent pulmonary complications such as atelectasis of the right lower or middle lobe or bronchopneumonia which might give rise to a condition of hypoxaemia Bandages should not impede easy breathing and affect the adequate respiratory exchange The importance of deep breathing and coughing must be explained to the nursing staff in order that they encourage the patients to do so The semi sitting posture which allows more free breathing to the patient and relieves the tension of the wound should be alternated with the supine position and turning the patient on

the opposite side every two to three hours Any drugs exerting a harmful effect on the respiration should be avoided Regular chest examinations, especially on the right side and in case of doubt, X ray examination, are necessary

The occurrence of *liver cell embolism* following hepatic trauma is a complication unfamiliar to most authors Jurgens (1886), Von Recklinghausen (1886) and Schmorl (1888, two cases) were the first to recognize the occurrence of embolic dissemina tions of liver fragments following traumatic injury to this organ According to Kaufman, the presence of liver cell em bolisms in the pulmonary artery is not an everyday observa tion and has so far been observed only microscopically (1931) This is not altogether correct, because the first case described by Schmorl was detected macroscopically in the pulmonary artery The same observation was made by Willer (1935) Usually, however, the emboli are only detectable microscopic ally, but they may still be the cause of death in the event of massive dissemination via the open hepatic veins It mostly occurs after crushing external injuries, but also following hepatic surgery The incidence of pulmonary embolism after liver surgery is high, and several of the cases reported were probably due to this cause

We therefore once more wish to emphasize the importance of *blunt division of the liver during operations, with ligation of* the hepatic venules crossing the plane of resection, before their division, a technique which we imagine, will at least partly circumvent this complication (see p 174)

Cholerrhagia Leakage of bile with localized abscess formation generalized biliary peritonitis biliary empyema or biliary fistulae have been described, especially in the period when conservative treatment of lacerations was still the rule Normal bile does not seem to cause as much harm as infected bile, the first is either encapsulated and slowly resorbed, or it gives rise

to an aseptic chronic peritonitis Infected bile causes fulminating peritoneal sepsis, leading to rapid death (Noetzel, 1910) All free bile should be removed during the operation, and there should be a careful check on leakage by compressing the gall bladder (see p 180)

Infections The frequency of abscess formation is reduced by leaving drains in the subdiaphragmatic space and against the area of liver resection In this type of surgery, however some devitalized liver tissue will always be spared, because by carrying the resection too far, healthy tissue will be involved in the end, resulting in haemorrhage

Although we do not wish to advocate the routine use of antibiotics, we still feel that these therapeutic agents (usually penicillin or aureomycin) should be given for a period of 7–10 days after the liver operation this opinion is based on the observations of Markowitz and others mentioned before

The devitalized liver tissue may have a twofold effect The first as a toxin released from the tissues by autolysis affecting both liver and kidneys (Mason *et al*) and the second on an inflammatory basis due to fulminating infection of dead tissue (Markowitz) Whether pre operative sterilization of the intestines which is most probably the source of infection ought to be recommended is an open question

Every abdominal infection as shown by Serege Wassink etc, is a severe drawback upon the liver and ought to be treated vigorously

Reverting to our point of departure it appears that the normal liver is endowed with a superlative reserve capacity which may however be impaired by a variety of factors As we have seen some conditions may recoil upon the general condition of the organ and reduce its reserve capacity

Any functional insufficiency there may be in the residual part of a resected liver is seldom due to one specific factor

Usually it is a number of coincident factors which are jointly responsible for the injury suffered by the cells of the liver

Disturbed hepatic function tests have shown that the functions of the liver are subject to failing compensation It is incumbent upon us to bring all our knowledge and energy to bear on the prevention of this *hepatic failure* by eliminating, as far as we can, every incipient cause of such a condition Hence the necessity for proper pre and post operative treatment of a patient undergoing hepatic surgery

Heyd, Boyce & McFetridge, Helwig & Orr, who made extensive studies of hepatic insufficiency after operations distinguish two forms of hepatic failure The first form, the acute type (liver death, Heyd 1923[1], usually becomes manifest immediately after the operation, it is characterized by hyperpyrexia, and tachycardia, associated with rapid development of lethargy, stupor and coma, death following within 18–36 hours after the operation Marked degenerative hepatic changes are generally found in this type

The second form is usually a subacute or chronic type of hepatic failure, mostly arising several days to weeks post operatively, if the functional decompensation resulting from surgical trauma is not counteracted Death follows within 10–14 days or even longer symptoms of severe renal insufficiency predominate in addition to more or less pronounced evidence of hepatic insufficiency progressive oliguria and the appearance of albumin casts and frequently erythrocytes in the urine Helwig and Schutz describe the clinical course as follows

The patient usually lapsed into a muttering delirium which rapidly progressed into coma and the nitrogenous elements of the blood greatly increased, while the urinary nitrogen strikingly decreased At about this time nausea and vomiting sometimes became prominent symptoms These latter symptoms were most marked in the post operative cases from the 5th to 8th day when with the removal of the stitches

a decided delay or even absence of wound healing was often observed Practically always some mucous surface bleeding was noted and in many instances it was so striking that the vomitus and stools consisted almost entirely of blood The clinical picture then progressed, as a rule to that of profound uraemia low grade generalized oedema developed and almost total anuria followed The retention of the nitrogenous products in the blood became more marked and the patient died in a state clinically resembling uraemia

This description is exactly that of the chronic hepatic insufficiency syndrome

Similar to cardiac decompensation which occurs when a new burden is thrown upon the circulation the liver is able to maintain a standard pattern provided that the reserve capacity is not needed however when the patient is subjected to a surgical operation the liver has no reserve capacity for sustaining this new burden Thus the liver permits the normal toxic substances from the intestinal tract to pass undetoxified into the general circulation These impurities plus toxic metabolites from necrotic liver cells overburden the kidneys with attempt to take over the duties of the liver (Boyce *et al*) When the kidneys are thus forced to assume the detoxifying function of the liver this added physiological necessity results in renal decompensation Hence it can be appreciated that initial hepatic exhaustion produces renal insufficiency and death (Ficarra 1950)

Both syndromes are the manifestations of the same process We believe that the so called liver death or hepatorenal syndrome is a single pathological process in which the hepatic changes always precede the kidney changes In our opinion if the patients who die promptly with hyperpyrexia and who exhibit liver degeneration at autopsy could be kept alive long enough they always would show precisely the same clinical and post mortem renal changes as do the patients who die later with typical symptoms of uraemia (Boyce *et al*)

Changes in the liver and the kidneys (convoluted tubules) vary from a light to severe degeneration

Prophylaxis should aim at preventing a large residue of devitalized liver tissue, because there is strong evidence that proteins, released from these devitalized parts, act as toxins, affecting both liver and kidneys (see p 148)

We do not propose to deal *in extenso* with the treatment of the various complications reference may be made to textbooks of internal medicine for treatment of the different forms of liver failure Our aim has been to point out the risks to which the liver—and hence the patient—is exposed and, wherever possible, to suggest in brief how such risks might be averted

EMPLOYED INJECTION CORROSION TECHNIQUE

The injection of intra organic hollow structures for the purpose of anatomical study was introduced around 1650 by some prominent Dutch anatomists, at a later date their methods were amplified by a number of corrosion techniques.

Joh van Horne professor of anatomy at Leyden University as becomes apparent (according to Hyrtl) from his Novum ductus chyliferus nunc primum delineatus Leidae 1652, introduced this technique to demonstrate the thoracic duct which had been discovered some years previously by Jean Pecquet independently of Olaus Rudbeck.

Reynier de Graef (1673 Leyden) developed an anatomical syringe which he only used for some physiological experiments performed in an endeavour to prove the correctness of Harvey's theory of the circulation of the blood.

The brilliant Johannes Zwammerdam doctor of Leyden famous for Algemeene Verhandeling van de Bloedelooze Diertjes (Utrecht 1669) and Miraculum naturae s uteri muliebris fabrica (Leyden 1672) not only described his method partly ut uteri aliaeque corporis cavitates (venae scilicet arteriaeque) ita praeparari possint ut genuinam suam faciem exhibeant et archetypi loco inserviant designandis earumdem figuris but also the material used for his injections Resipe cerae albae quantum videbitur eamque lique factum rubro flavo viridi vel alio colore tinge et siphone qui

cochleæ adstrictum tubulum habeat ... etc.' He was the first to describe the intrahepatic ramifications of bile ducts and arteries.

F. Ruysch *corroded his injected specimens, but both meth*ods are unknown, because he kept them secret.

Lieberkuhn (Berlin, 1750) described, next to a number of materials he used for injection purposes (mixtures of wax, with colophononium and turpentine added, etc.), some corrosion media, such as esprit de nitre, assez fort (nearly concentrated nitric acid) or sulphuric acid, detempte dans l'eau, jusqu'à ce que l'acide ait dissous ce qui n'est pas dans la cire, etc.

One of the greatest authorities on injection corrosion anatomy was Hyrtl, who made an extensive study of practically *every hollow structure of the human body* and of animals, including the heart and its vessels, lungs, liver, spleen, kidneys, etc. His book 'Die Corrosionsanatomie und ihre Ergebnisse', Vienna 1873, embodies the results of 12 years of injection corrosion anatomy.

The introduction of X-rays in medicine enabled a method of investigation to be evolved (developed by Von Hildebrand *1907) by which radio-opaque media are injected into the* intra-organic hollow structures. Martens (1920) used this technique to study the intrahepatic course of the hepatic arteries. Segall (1923) did the same for all the intrahepatic structures, following which this method was used by several other authors for the same purpose.

Since the discovery of plastics and similar products, these materials have been used *as an injection medium in the injec*tion corrosion technique, at first applied to the study of the anatomy of pulmonary structures and the vessels of the heart, more recently to that of the liver as well.

Method

A pressure chamber obtained from an old-fashioned discarded *autoclave was divided into four compartments* (fig. 114). Each

compartment was drained by a metal tube Pressure was applied by means of compressed carbon dioxide, which was passed through two pressure reducing valves, the second one



Fig 114 Injection apparatus 1 inlet valve 2 four compartments 3 four draining tubes with cocks

being used to check the pressure in the chamber After passing these valves the gas proceeded via rubber tubings to an inlet at the top of the apparatus The four compartments contained

plastic of different colours The various hollow structures were cannulated by means of glass tubes and connected with the pressure chamber through rubber tubings The livers, obtained at autopsy from the Department of Pathology of St Canisius Hospital of Nijmegen, were thoroughly cleaned by mechanical means prior to injection Moreover, the cancerous livers were insufflated with compressed carbon dioxide During the injection, the liver floated on water The portal vein and bile ducts were injected under a pressure of 0 1 atm, the proper hepatic artery with a pressure of 0 4–0 5 atm and the hepatic veins with a pressure lower than 0 05 atm The arteries were first injected till the arterial vascular bed was completely filled, which was observed as a cessation of the flow of plastic in the glass connection pieces between the rubber tubings Re injections followed in the next half hour, to compensate the shrinkage of the material Subsequently, the bile ducts and portal veins were injected The hepatic veins were the last to be dealt with

The plastic was re injected several times on the same day and the following day after complete solidification of the plastic, the liver was placed in a concentrated hydrochloric acid solution (45%) for 3–5 days Removal of the remnants of liver tissue was effected by means of a fine jet of water from a nozzle The plastic which we used was prepared in our laboratory from polyvinylite (supplied by Waterhouse Mason & Co Rotterdam, Holland) and acetone

2000 grams of polyvinylite were added to 5000 cc of acetone The suspension was shaken by hand or with the aid of an adapted machine (as used in serology) until the solid was dissolved We also used plastoid for injection purposes (supplied by Rohm & Haas Darmstadt, Germany) Pigments were added which met the specifications drawn up by Liebow et al namely, they mixed well with the plastic, they were not affected by the concentrated hydrochloric acid and they did not bleed

Those colouring materials were
red (hepatic artery) mercuro sulphide
blue (portal vein) prussian blue
yellow (bile duct) picric acid
white (hepatic vein) kaolin

Later we used the various pigments supplied by Rohm & Haas because they suited our purpose so much better

Material

Our study is based on over 100 coloured polyvinylite corrosion specimens of normal human livers 15 specimens of cancerous human livers 3 dog livers and 1 pig's liver The anatomy of the dog's liver will be discussed briefly and compared with the human liver, because part of our hepatic surgical experience was gained on dogs In spite of the considerable differences in the intrahepatic structures of these two livers there is sufficient resemblance so that with these differences and similarities in mind the liver of the dog may be of great practical use for experimental purposes Only a few of the organs were injected *in situ* mainly in order to study the intra and extrahepatic courses of the portal vein in their natural relationship to each other Dissections of the hilum of approximately 25 fresh as well as injected specimens were carried out to study the hilar anatomy for surgical purposes The nomenclature proposed in this study is restricted to the ramifications of the first and second order It is a topographical one comparable with those used in the past for other organs

Appendix II

HEPATOGRAPHY

The practical implications of the anatomical data are certainly not only of value to surgery. In future they will undoubtedly be useful for diagnostic purposes as well.

Liver function tests, which are useful in the determination of the extent of liver damage and its response to treatment, usually fail to give any definite information in case of tumours of the liver (Thomas & Zimmerman, 1952).

Up to the present hardly any attempts have been made to study the anatomical peculiarities (see p. 170) or certain diseases (see p. 133) of the liver by injecting radio-opaque substances into the hollow structures during operation and taking X-ray photos of these structures. Yet operative cholangiography, as used for the diagnosis of stenosis of extra-hepatic ducts, may very well suit these purposes.

Several attempts to visualize the hepatic structures *in vivo* for diagnostic purposes have been described recently. These procedures may moreover be instructive as to the intrahepatic anatomy of one particular liver, for instance one selected for operation.

Operation is avoided in *transabdominal cholangiography*, as *recently developed by Carter & Saypol (1952)*. A needle or trocar is pushed slowly through the abdominal wall into the liver substance. If the needle pierces the wall of the duct, the resistance increases, diminishing again if the point enters the

lumen of the duct Withdrawal of the stilette at this moment is followed by flow of bile (especially in cases of obstructive jaundice) This method was initially tried out during exploration The bleeding from the needle puncture and the drainage of bile from a dry tap were slight and subsided promptly

Radio opaque substances, injected through the needle, will cause filling of all intrahepatic bile ducts, provided both hepatic ducts are open However, transabdominal cholangiography performed along these lines seems to us a difficult and hazardous procedure

Operative portal phlebography, and more recently *transabdominal portal phlebography* (Abeatici & Campi 1951) can be utilized for the same purposes though up to now it has only served for diagnosis of portal vein obstructions Several reports have already appeared on its diagnostic use since its introduction (Leger Middlemiss 1954, Aung 1954 and others)

The spleen is punctured with the patient under general anaesthesia, on the side of the anterior axillary line in the 9th–10th left intercostal space and a needle about 15 cm long is inserted in the antero-posterior direction, the patient holding his breath for a few seconds If however some disturbance of the blood clotting mechanism is expected, the puncture is carried out immediately before the operation with a thin needle A scratching sound is heard at the moment when the needle strikes the capsule of the spleen Blood can be aspirated when this capsule has been passed The back flow may be forceful in the event of portal hypertension If dye is injected into the spleen this organ will contract under the influence of the stimulation and the dye will be distributed over the portal vein system This method has only been used up to the present day for the diagnosis of portal obstruction and the examination of the collateral circulation The procedure was carried out in dogs by Tori & Scott who did not find any macroscopical or microscopical histopathological changes of the spleen



Fig 11[illegible] Large nodular metastatic carcinoma of the liver (primary tumour in the breast) No filling of veins and arteries at this site



Fig 116 Detail of the notch caused by the tumour in the previous photograph

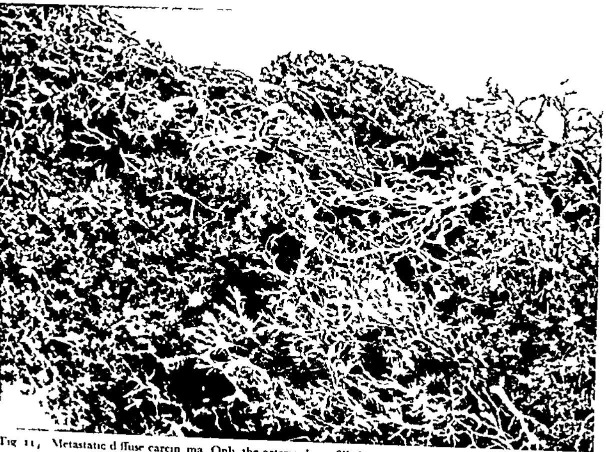
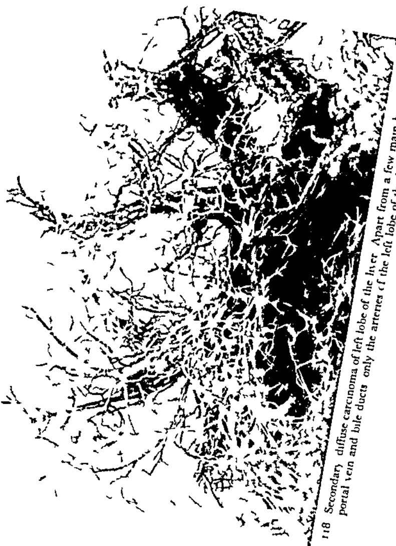


Fig 114 Metastatic diffuse carcinoma Only the arteries have filled in the area between the arrows (primary tumour carcinoma of the stomach)



118 Secondary diffuse carcinoma of left lobe of the liver Apart from a few main branches of the portal vein and bile ducts only the arteries of the left lobe of the liver have filled



Fig 119 Sketch in hepatic vein specimen at the site of a nodular carcinomatous metastasis.



Fig 120 Nodular metastatic carcinoma of the liver (primary carcinoma of the rectum) Abnormal arteries in the growth Veins and bile ducts not filled in situ

Middlemiss, after using this method in 26 patients, did not observe any bleeding and the experience of all other investigators employing this procedure (Leger, Aurig, and others) was the same. If there is no extrahepatic portal obstruction, the major intrahepatic portal vein branches are filled in this way.

In 1952 Tori developed a method of visualizing the hepatic veins by passing a cardiac catheter into the inferior vena cava via the right auricle. By inserting the tip of the catheter alternately into the right and left hepatic vein, each vein was injected with 70% diodrast, the patient holding his breath as in the Valsalva test (to obviate backflow of the dye). Hepatic venograms produced in this way showed local pathology.

What is to be expected of the hepatogram of a patient with metastases in the liver and which structure, after injection, is likely to provide the most revelatory data for a diagnosis? In an endeavour to find the right answers to these questions, we also injected carcinomatous livers at the very outset of our research because this procedure enabled us to study the circulation of the blood in the affected part.

Breedis and Young (1954), who also investigated the blood supply of hepatic tumours, arrived at the conclusion "that *malignant neoplasms growing in the liver tend to acquire an exclusive arterial blood supply*". This opinion was based on the study of specimens of livers injected with India ink and coloured gelatin. Prior to the appearance of their paper, our results of the study of the injection corrosion specimens of livers—with secondary tumour growths varying from 1–10 cm in diameter in 15 specimens—were that there are two types of secondary tumour growths, each of which shows a different relationship to the hepatic artery.

The first type is that usually encountered, which is characterized by the appearance of a circumscribed nodule (figs. 115 and 116).

The second type, which was only twice encountered in our

series of specimens is not the round, circumscribed form probably on account of the more invasive growth The macroscopic picture of this type is a streak of tumour tissue (fig 117), usually a wide band of varying length occasionally involving a whole area (fig 118) This type of tumour reminds us of the way in which cancer of the gall bladder extends into the liver We originally named this type of growth the diffusely growing type it would perhaps be better to speak of a locally diffuse growing type of metastases

Both types when occurring as secondary growth start as a small tumour embolus in the liver The *nodular type* grows out eccentrically and pushes aside the normal liver tissue as well as the local hollow structures

None of the intrahepatic structures at the site of the nodule proved to be filled with polyvinylite in our casts Occasionally some minor hepatic arterial branches may penetrate usually a very short distance into the periphery of the tumour nodule In this type the larger branches curve around the tumour nodules with a definite displacement curvature in their course (both arteries and veins) (fig 116)

We did not investigate whether the structures originally present at the site of the nodule atrophied during the process of extension of the tumour during which these structures were pushed aside or became occluded (by invasion or compression) In the *diffusely growing type* however the arteries and most of the bile ducts are not occluded not even the tiny branches the portal vein branches are except for some major branches (fig 118) totally occluded

In cancer of the gall bladder the liver is invaded on either side of the fissura media all structures being occluded except some very small hepatic arterial branches penetrating not further than into the periphery of the tumour growth In this case the growing tumour pushes aside the major arterial branches and very many of these branches are re-discovered at the border line between tumour and normal liver tissue

None of the structures in the vicinity of the tumour are filled however, which provides evidence of a considerable pressure exerted on these vessels, with or without occlusion from within *by thrombosis and/or invasion by tumour cells*

The practical lesson afforded by this fact is that in all types of secondary hepatic malignancies the portal vein branches are occluded The possibility of utilizing this fact for diagnostic purposes ought to be considered Phlebography prior to surgery, as described by Abeatici and Campi (1948), or during surgery, by injecting 35–70% diodrast into the *superior mesenteric vein, may prove to be a valuable diagnostic* procedure for ascertaining whether there are metastases in the liver (if they are large enough to become detectable in this way), where they are localized (which requires a proper knowledge of the normal anatomy) and how many metastases are present

bon nombre de jeunes condisciples futurs chirurgiens sont tout à fait erudits sur les moindres rameaux de la maxillaire interne ou sur les moindres variétés des arcades palmaires ou plantaires alors qu'ils possèdent des notions souvent rudimentaires sur l'anatomie de l'artère hépatique

With these words Rio Branco in 1912 introduced his truly authoritative study Although in the forty years or so that have passed since this study was first published the various views and ideas in surgery have undergone radical changes—by no means least those concerned with the position and significance of anatomy this development has gone by imperceptibly in hepatic surgery with the result that this branch of surgery is still in almost the same condition as around 1880–1890 This in itself would be nothing unusual were it not that the various methods that have been developed possess disadvantages which have deterred many from applying them

We have therefore reviewed briefly the various methods of partial liver resection that have been described together with their attendant drawbacks We now consider that a great number of these drawbacks no longer apply in that form of surgery which takes into account the anatomical structure and special features of the liver For this reason also the first part of this work is devoted entirely to a study of the anatomy of this organ and its internal structure

With regard to the division of the liver it appears that from its outward appearance it can be divided not only into a right and left lobe with the attachment of the ligamentum falciforme as the dividing plane—as one usually finds it in the textbooks—but also and in our opinion much more correctly into a left right and middle lobe as has already been suggested by Ruge and De Burlet The middle lobe can be further subdivided into two or three lobes

When one studies the behaviour of the structures of the Glissonian system with the help of the findings in corrosion preparations it seems that the intrahepatic flow bed of this system splits into two halves both of which are subdivided into lobes and some of these can be subdivided into segments In comparing the areas distinguishable as such in the liver with the external subdivisions of the organ observed by Ruge and De Burlet the lobes described by these authors appear to a certain extent to correspond to those areas

We have naturally attempted to give an embryological explanation for this subdivision of the liver Although there are definite indications that these subdivisions are indeed founded along the *lines on which the intrahepatic venous systems develop*, we feel at the same time that insufficient data are as yet available to support this view and that further research is advisable

It is impossible to summarize in a few words the topographical relationship of the various structures of the Glissonian system especially since they show such great variability We therefore refer the reader to the chapters concerned (III and IV) in which with *the help of several diagrams, the most frequently occurring pictures* are reproduced

The vena hepatica system is in this respect simpler Next to the venae hepaticae majores one can discern the venae hepaticae breves The former are naturally of most interest to us and amongst them we can *distinguish the vena hepatica dextra sinistra and media These hepatic veins lie in the interlobar fissures of the* Glissonian system, i e , the vena hepatica dextra in the right the vena hepatica sinistra in the left interlobar fissure and the vena hepatica media in the median fissure

One may wonder to what extent the intrahepatic vascular system opens perspectives in the surgery of the liver It appears *that neither the division of the Glissonian system nor that of the* vena hepatica system forms in itself a satisfactory basis, yet when one combines both of these one arrives at a division into three surgical liver lobes each having its own afferent and efferent systems at both hepatic gateways

The principles of hepatic surgery based on the morphology of the liver can be deduced easily from the preceding remarks In this form of surgery the pivot of the method lies in the ligation at the liver hilum of the Glissonian structures in that part of the liver to be resected and of the corresponding branch of the vena *hepatica at the cranial pole of the liver It is then pointed out that* the interlobar fissures dividing the lobes from each other are the indicated planes along which the resection should be made

This method has the advantage that it partly or entirely eliminates the complications of classical hepatic surgery viz the chance *of bleeding and cholerrhagia and—if properly applied—*the chance of damage to afferent and efferent structures of the remaining part of the liver

In considering the various surgical questions one cannot escape the problem which incisions enable the surgeon to reach the differ

ent parts of the liver It is self evident that the incision must depend on the nature of the resection A number of these incisions were checked on cadavers and are discussed in Chapter IX

Further we felt that we should consider the therapeutic consequences of hepatic surgery We take the view that for this radical surgery resection should be considered only for those pathological affections with which every other form of therapy will certainly or almost certainly fail We have therefore provisionally drawn up the following list of indications for resection primary solitary malignant growths isolated metastatic tumours carcinoma of the gall bladder in the initial stage of its invasion of the liver and deep lacerations of the liver

Finally in the last chapter various physiological and clinical aspects connected with hepatic surgery are briefly discussed

Many problems remain unsolved Among the ones not yet investigated are those concerning the innervation of the liver the role that the liver plays in the circulation of lymph and the influence on them of possible damage during surgery Other problems less directly concerned with the subject are just touched on

If this work is able to render successfully some of the most important aspects of the anatomy and surgery of the liver and to interest some investigators in the problems yet to be solved it will have fulfilled its purpose

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